

Chapter 7: Conservation of Listed Species: the Northern Spotted Owl and Marbled Murrelet

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Introduction

The statement of mission for the Forest Ecosystem Management Assessment Team directed the team to take an ecosystem approach to forest management and particularly to address maintaining and restoring of biodiversity. In addressing biological diversity, the team was directed to develop alternatives that met the following objective:

maintenance and/or restoration of habitat conditions for the Northern Spotted Owl and the Marbled Murrelet that will provide for viability of each species -- for the owl, well distributed along its current range on federal lands, and for the murrelet so far as nesting habitat is concerned

—FEMAT (1993: iv)

In this chapter, I describe the expectations of the Northwest Forest Plan (the Plan) in meeting this biodiversity objective and assess how successful it has been in its first 10 years. In judging progress, keep in mind that the Plan's outcomes were expected to evolve over a century and longer. Thus, discerning progress after only the first decade is difficult. But a focus on the Plan's progress in meeting these goals for two wide-ranging vertebrates, the northern spotted owl and

marbled murrelet, both of which are listed as Threatened under the Endangered Species Act (1973), is certainly warranted.

Northern Spotted Owl

The northern spotted owl conservation strategy embodied in the Plan evolved from designation and protection of a large number of relatively small management areas for individual pairs of owls to an approach based primarily on the designation of fewer large areas, each designed to support multiple pairs of owls. The scientific basis for the current strategy was developed by the Interagency Scientific Committee (ISC, Thomas and others 1990). The ISC articulated five general principles from the field of conservation biology that formed the scientific underpinning of their owl conservation strategy:

- Species that are well distributed across their range are less prone to extinction than species confined to small portions of their range.
- Large blocks of habitat, containing multiple pairs of the species in question, are superior to small blocks of habitat with only one to a few pairs.
- Blocks of habitat that are close together are better than blocks far apart.
- Habitat that occurs in less fragmented (that is, contiguous) blocks is better than habitat that is more fragmented.
- Habitats between blocks function better to allow owls to move (disperse) through them the more nearly they resemble suitable habitat for the species in question (that is, blocks that are well connected in terms of habitat are better suited than blocks that are not).

Using these principles, the ISC called for the delineation and conservation of blocks of suitable northern spotted owl nesting, roosting, and foraging habitat (hereafter termed “habitat”), most large enough to support 20 or more pairs of owls and spaced no more than 12 miles apart, and the provision of dispersal habitat in areas between blocks of nesting habitat.

The FEMAT incorporated the northern spotted owl conservation principles from the ISC as well as broader considerations for other species associated with late-successional and old-growth forest, functional old-growth ecosystems, and aquatic ecosystems, and developed 10 management options. One of these, Option 9, was selected and further developed, eventually becoming the Northwest Forest Plan. All of the options included extensive reserve systems, that is, federal lands reserved from planned commercial timber harvest and for which the primary objective was maintaining and restoring late-successional and old-growth forest. These reserves included wilderness and national parks, other administratively withdrawn lands, and two new classes of reserves called Late Successional Reserves (LSRs) and Riparian Reserves. In the Plan, these LSRs were designed to include the best of remaining late-successional and old-growth forest along with Key Watersheds (FEMAT 1993), and additions to meet the recommendations from the ISC and the draft Northern Spotted Owl Recovery Plan (USDI 1992). Riparian Reserves were buffers along permanent and intermittent streams where forest habitat is to be retained (See Reeves, chapter 9 this volume). Under the Plan, these riparian reserves were assumed to provide connectivity among the larger LSRs to support owl dispersal.

What was Expected Under the Plan?

The FEMAT (1993) used an expert panel to assess the sufficiency of habitat on federal lands to support a viable population of the northern spotted owl over a 100-year projected period. The panel considered four possible outcomes, labeled A through D. Under Outcome A, habitat was judged to be of sufficient quality, distribution, and abundance to allow the owl population to stabilize, well-distributed across federal lands over the next 100 years. Note that this outcome does not imply a **constant** population, but rather one that might vary around some nondeclining mean population. Under Outcome B, habitat would allow the owl population to stabilize but with significant gaps in the historical distribution that could cause some limitation in interactions among local populations. Under Outcome C, habitat would be so limited as to allow owl persistence in refugia with strong limitations on interactions among local populations. Outcome D represented extirpation of owls from federal lands. The expert panel assigned an 83 percent likelihood to Outcome A and an 18 percent likelihood for Outcome B with no likelihood of Outcomes C or D for Option 9, the option that eventually was developed as the Plan. Thus, the panel's assessment was the high likelihood that habitat conditions on federal lands would allow the northern spotted owl population to stabilize and be well-distributed throughout its range. Note also that additional features added to Option 9 after FEMAT in the Record of Decision (ROD, USDA and USDI 1994b), such as an increase in the width of riparian buffers on intermittent streams and protection of a 100-acre area around owl activity centers in the Matrix, would likely provide for an even higher likelihood in Outcome A had these features been evaluated by the expert panel. In summary, the Plan "would adequately provide for the continued viability of the northern spotted owl on federal lands as required by the National Forest Management Act (NFMA 1976) and furthermore would provide the federal lands' contribution to recovery of the northern spotted owl under the Endangered Species Act (ESA 1973) (USDA

and USDI 1994b: 31). I emphasize, however, that this projection was based on whether habitat conditions on federal lands would support owls. The panels recognized that the cumulative effects of habitat conditions on nonfederal lands, interactions with the barred owl, and other factors outside the scope of the Plan, would produce much greater uncertainty in the projected likelihood of owl persistence. The FEMAT also assess Option 7, an option that was based provisions of the draft recovery plan for the owl and which was very similar to the proposals if the ISC. Outcomes for that option were lower than Option 9, with scores of 71, 25, 4, and 0 for Outcomes A, B, C, and D.

Clearly, over the long term, the Plan was expected to provide for a well-distributed and viable population of the owl but no quantitative description of expected short term trends was forthcoming. Several qualitative descriptions exist, however. Because the Plan is based so strongly in the ISC recommendations, it is instructive to examine its expectations. The ISC wrote (Thomas and others 1990: 35):

An implied assumption of this conservation strategy is that the owl population will reach a new, stationary equilibrium at some future time. We are confident in this assumption, even though the amount of suitable habitat and the number of owls will continue to decline over the short term. We hypothesize that once the rate of loss of suitable habitat outside HCAs [Habitat Conservation Areas] comes into balance with the rate new habitat is recruited within the HCAs, a stable equilibrium will be attained. This equilibrium will, of course, be at a lower population number that existed historically. Further, because the northern spotted

owl has a low reproductive potential, considerable time may be required for the population to stabilize at a new equilibrium number.

The ISC anticipated declines of up to 50-60 percent of the current owl population under their conservation strategy. The northern spotted owl recovery team projected that owl habitat and owl numbers would continue to decline for up to 50 years before reaching a new equilibrium under the draft recovery plan, which was very similar to the ISC strategy in the size and number of its habitat reserves (USDI 1992).

The Plan provides for a 52 percent larger system of habitat reserves than did the ISC strategy (comparing Options 7 and 9, in the final supplemental environmental impact statement [FSEIS], table 3 and 4: 38 in USDA and USDI 1994a). Under the Plan, owl numbers and amounts of habitat were still expected to decline but at a slower rate than under the ISC strategy. Habitat was expected to decline from timber harvest by about 2.5 percent per decade (USDA and USDI 1994b: 46). In the FSEIS, continuing population declines were also expected. It discussed at some length whether, given the results of demographic studies showing declining survival rates of adult owls, the owl population might have passed a population threshold from which it could not recover. The 1993 demographic analysis (Burnham and others 1996) estimated a 4.5 percent annual decline (confidence interval = 0.7 to 8.4 percent annual decline) in the population of territorial adult owls. In considering available evidence, the FSEIS team concluded that the basis for believing that owl populations have passed or would soon pass a threshold was not strong. This conclusion was supported by Raphael and others (1994), who performed a series of owl population simulations based on projected habitat trends under assumptions of Alternative 9.

These spatially-explicit population models suggested that populations might decline in most provinces for the first 40-50 years, but populations in all areas eventually stabilized and began increasing as habitat recovery exceeded losses. In the Oregon provinces, populations did not show initial declines. Raphael and others accounted for timber harvest outside of the reserves, and for ingrowth of habitat in the reserves, but did not model losses of habitat to fire or other catastrophic events. In these simulations, Raphael and others did not account for habitat that might be on nonfederal lands.

The northern spotted owl monitoring plan also provides several qualitative descriptions of anticipated trends in populations and habitat (Lint and others 1999):

- Owl populations are expected to continue to decline over the short term with the decline proceeding at a faster rate for owls in the matrix than in reserves.
- In the longer term, owl populations in reserves are expected to be self-sustaining as individual reserves reach a condition where at least 60 percent of the land area is comprised of owl habitat.
- Habitat conditions within reserves will improve over time at a rate controlled by successional processes in forest stands that currently lack the vegetation structure to be owl habitat.

- Habitat conditions outside of the reserves will generally decline because of timber harvest and other habitat-altering activities, but the vegetation structure across the landscape will continue to facilitate owl movements.
- Catastrophic events are expected to halt or reverse the trend of habitat improvement in some reserves; however, the repetitive design of the reserves should provide adequate resiliency in the reserve network, so catastrophic events do not result in isolating segments of the owl population.

What has Happened to the Owls and What Differences Were Found Between Expectations and Observations?

Baseline habitat—

The Plan was designed using many of the principles of conservation biology and was expected to conserve much of the remaining northern spotted owl habitat in large reserves. Davis and Lint (in press) used a modeling approach to define and map owl habitat. They first defined “habitat capable” lands as those areas capable of growing forest within the elevation range in which owls are known to nest. Then, using a software package called BioMapper, Davis and Lint classified habitat capable lands into habitat suitability for nesting, roosting, and foraging ranging from 0 (lowest suitability) to 100 (highest suitability). The resulting habitat suitability maps depict the full range of scores, from 0 to 100. In some cases, reporting amounts of northern spotted owl habitat required setting a threshold for suitability and tallying all acres that exceed that threshold. Davis and Lint generally chose to consider areas with scores greater than 41, based on the range

associated with 90 percent of known owl sites, to define a range that is most similar to areas where owls were known to occur. Under that criterion, about half (48 percent) of lands capable of supporting owl habitat are on federally administered lands within the Plan area (of 42.1 million acres of federal and nonfederal habitat-capable land); federal lands support 59 percent of owl habitat. Note that the remaining 41 percent of total owl habitat is on nonfederal land (Davis and Lint, in press) over the entire owl range. It is likely that habitat on nonfederal lands is in smaller, more fragmented patches than habitat on federal lands. On federal lands, about 60 percent of habitat-capable land is in reserved land use allocations (excluding Riparian Reserves, which are not mapped) and 65 percent of owl habitat is in those allocations (fig. 7-1). Davis and Lint assumed that as much as 50 percent of the habitat-capable lands in Adaptive Management Areas and the combined Matrix/Riparian Reserves would be reserved and under that assumption they estimated that over 80 percent of the habitat-capable acres with habitat suitability >40 would occur in a reserved land use allocation. In Washington, Oregon, and California, percentages of owl habitat in reserves (not counting Riparian Reserves) are 79, 61, and 61, respectively. This indicates that the reserved land allocations were somewhat successful in including acres of the most suitable habitat.

The FSEIS estimated that about 66 percent of the extant owl habitat (totaling about 7.4 million acres on federal land) would be in Congressionally Reserved Areas and Late-Successional Reserves (USDA and USDI 1994a: 222). Davis and Lint (in press) estimated that about 59 percent of owl habitat (that is, habitat with suitability score of 41 or greater, totaling 10.3 million acres on federal land rangewide) would be in these two types of reserves. Additional habitat is reserved under other land use allocations such as Administratively Withdrawn Areas, Riparian

Reserves, Marbled Murrelet Reserve Areas (LSR3), and 100-acre northern spotted owl Core Areas (LSR4). The areas of these types of reserves are difficult to compare between Lint's analysis and the FSEIS because the FSEIS did not report these areas, so here we focus on the Congressionally Reserved and Late-Successional Reserve Areas. Davis and Lint's analysis suggests a smaller proportion of owl habitat was retained in these two land use designations than was estimated in the FSEIS. Also apparent is that Davis and Lint's estimate of the total amount of baseline habitat is greater than was estimated in the FSEIS. The difference in amount is a consequence of the difference in methods used to classify habitat and because the FSEIS did not include estimates for Bureau of Land Management and National Park lands in California (FEMAT 1993: IV-38); I believe the Davis and Lint estimates are an improvement over previous estimates because the data and methods used to classify habitat were more consistent across the owl's range.

Habitat losses—

The expected rate of loss of owl habitat from timber harvest on federal lands was 2.5 percent per decade (USDA and USDI 1994b: 46). Davis and Lint (in press), using change detection methods from Moeur and others (in press), estimated that losses on federal lands from stand-replacing harvest of owl habitat (that is, losses of acres with habitat suitability scores of 41 or greater) were 0.26 percent, rangewide, over the past 10 years and varied by state: losses totaled 0.11 percent in Washington, 0.35 percent in Oregon, and 0.19 percent in California. Among provinces, losses were greatest (0.79 percent) in the California Cascades; no other province lost more than 0.5 percent. Clearly, loss of habitat from timber harvest on federal lands (at least those losses from stand-replacing harvest) was below the expected 2.5 percent per decade. There were no estimates

of expected rates of loss on nonfederal lands. Observed harvest rates were substantially greater on nonfederal lands than on federal lands: losses totaled 8.0 percent rangewide, 12.0 percent in Washington, 10.7 percent in Oregon, and 2.2 percent in California.

Losses of habitat from wildfire were greater than losses to timber harvest. Although losses from catastrophic events such as fire or windthrow were anticipated, I found only one quantitative estimate of expected rates for such events: FEMAT (1993: IV-55), in conducting simulation studies to estimate forest development, assumed that 2.5 percent of reserved areas (on average over the Plan area) would be subject to severe disturbance per decade. Observed rates averaged over the entire Plan area have been lower than the FEMAT estimate, but rates on the Oregon Klamath, Eastern Cascades of Washington, and California Cascades provinces were greater than 2.5 percent per decade (Spies, Chapter 6, this volume). Davis and Lint (in press) estimated rangewide losses of 1.3 percent of habitat-capable acres with a habitat suitability >40 from wildfire on federal lands. Most of this loss was in the Klamath Province of Oregon after the Biscuit Fire. In that province, 6.6 percent of owl habitat was lost, mostly in large reserves. Rates of loss in all other provinces were less than 1.5 percent. Rates of loss to fire totaled 0.4 percent in Washington, 1.9 percent in Oregon, and 1.3 percent in California. Losses to fire were less on nonfederal lands, totaling 0.1 percent rangewide. Losses were 0.04 percent in Washington, 0.2 percent in Oregon, and 0.1 percent in California.

On average, the combined loss from harvest and fire on all lands totaled 4.3 percent rangewide during the Plan's the first 10 years. The rate of loss was greatest in Washington (5.2 percent). Loss totaled 4.3 percent in Oregon, and 1.9 percent in California. The total loss from harvest and

fire on federal lands (1.6 percent) was substantially lower than was assumed in the FEMAT simulations (5.0 percent).

Bigley and Franklin (2004) summarized changes in owl habitat as part of the recently completed northern spotted owl status review (Courtney and others 2004). They relied on estimates of loss compiled from agency records by the U.S. Department of Interior, Fish and Wildlife Service (FWS). The FWS numbers differ from those summarized in Lint, primarily because the FWS definitions of suitable owl habitat differed, the FWS used agency records rather than satellite-based, change detection, and because the FWS included partial harvest in their calculations (Moeur and others, in press were not able to estimate acres of partial harvest by change detection methods). I do not know the extent to which partial harvest affects owl habitat: some amount of harvest may improve habitat in parts of the owl's range and may degrade habitat in other parts of the range. The FWS reported a loss of 380,000 acres of owl habitat from 1994 to 2003; 156,000 from harvest and 224,000 from natural events (fire, wind, insects, and disease). The FWS baseline was 7.4 million acres, similar to that used in the FSEIS. The rate of loss was thus 5.1 percent per decade, an estimate more than twice that of Davis and Lint's estimate, but roughly in line with assumptions in FEMAT and the ROD (2.5 percent loss from fire and 2.5 percent loss to harvest, totaling 5.0 percent per decade).

Habitat increases—

Amounts of habitat were expected to increase over time as young forests mature and gain the characteristics of suitable owl habitat. Davis and Lint (in press) were not able to fully account for growth of owl habitat. Moeur and others (in press), however, estimated a net annual increase of 2

percent per year of forest with trees greater than 20 inches diameter at breast height (d.b.h.) over the past decade. Davis and Lint acknowledged that they cannot directly crosswalk Moeur and others's estimate to infer increases in suitable owl habitat, but they estimated that about 85 percent of the acres of late-successional forest mapped by Moeur and others (in press) was coincident with owl habitat suitability scores >40 . Moeur's data suggest a net increase (over and above losses from harvest and fire) in older-age forest. Davis and Lint (in press) assumed 85 percent of that increase (515,000 acres) transitioned into suitability >40 , with the result that there might have been a 5 percent increase in habitat-capable acres with suitability score >40 during the monitoring period. They suggest that longer term increases in amount of habitat will accrue for forest that is currently in the lower suitability classes (that is, those acres currently scoring in the 21-40 range). They further suggest that the greatest increases in habitat will likely be in the Western Cascades of Oregon and Washington, the Klamath Provinces of Oregon and California, and the Coast range Province of Oregon where more than two-thirds of the habitat-capable Plan acres are.

As shown in figure 7-2, the amount of habitat capable land area with suitability scores ≤ 40 is larger on nonfederal lands. This might reflect the heavier rates of timber harvest on those lands. In addition, based on current harvest practices on most nonfederal lands (e.g., short rotations), amounts of forest with these lower suitability scores will likely not progress toward higher scores over time, as they are anticipated to do on federal lands (as older plantations develop into habitat). In other words, low-suitability nonfederal habitat is probably more static and recruitment of future habitat will mostly occur on federal lands. On federal lands, habitat recruitment can be anticipated from forest with habitat suitability ≤ 40 .

In summary:

- Most owl habitat is on federally administered lands, but a substantial amount of habitat (41 percent) is on nonfederal lands.
- Nonfederal habitat may not function as well as federal habitat in supporting owls to the extent it is in smaller more fragmented patches.
- Most (65 percent) of habitat on federal lands is in reserved land allocations.
- Losses of habitat on federal lands from harvest were variable across the owl's range; losses from harvest were less than expected under the Plan.
- Additional losses of owl habitat resulted from fire and other disturbances, which were most severe in the Oregon Klamath province because of the recent Biscuit Fire, and rangewide loss of habitat from fire was lower than expected under the Plan.
- Loss of owl habitat to fire and especially to harvest was much greater on nonfederal lands.
- Some evidence showed a net increase in amounts of mature forest (stands greater than 20 inches d.b.h.) during the first 10 years of the Plan, but how much of this increase is owl habitat is unclear. Increases in acres with suitability >40 might have exceeded 5 percent.

Population trends—

Estimates of northern spotted owl population trends derived from the most recent demographic analyses are fully described in Anthony and others (in press) and in the northern spotted owl status and trend report (Lint, in press). These reports provide a full explanation of the methods and details of the analyses; here I extract a few of the key results:

- The rangewide population, averaged across all 13 demographic study areas, declined by 3.7 percent per year from 1990 to 2003 (weighted mean $\lambda = 0.963$, $SE = 0.009$). “Lambda” is a measure of the rate of population change; a value of 1.0 indicates a stationary population, a value less than 1.0 indicates a declining population, and value greater than 1.0 indicates a growing population. A declining population is consistent with the expected trend; the rate of decline is greater than one might have predicted from the rate of habitat loss and is less than the 4.5 percent annual decline that had been estimated from the 1993 demographic analysis. The estimated rate of change was based on a different analytical model in the 1993 analysis (see Boyce and others 2005 for a discussion of the newer approach) and so estimates from the 1993 and 2004 analyses are not directly comparable.
- Rates of decline vary across the owl’s range, with the greatest decline (and an accelerating rate of decline from higher rates of mortality) in Washington and the northernmost Oregon site (weighted mean $\lambda = 0.925$, $SE = 0.008$) and lower rates of decline in the remaining study areas in Oregon and California (weighted mean $\lambda = 0.980$, $SE = 0.004$).¹ Populations were declining in Washington and the northernmost study area in Oregon, where apparent survival rates were declining on those five study areas. Populations were essentially stationary on the remaining five study areas in Oregon (that is, the 95 percent confidence intervals around λ overlapped 1.0). Variation in rates of population change in different parts of the owl’s range was expected, based on known differences in amounts and distributions of habitat across the range and based on evidence from the simulation modeling. The magnitude of decline and accelerating rate of decline in Washington was not expected, however, nor was the apparently stationary trend in parts of Oregon.

- Realized population change in Washington indicated a loss of 40-60 percent of the initial population in those study areas during the 13 years of study (illustrated for one study area in figure 7-3; note the wide confidence interval around this cumulative effect). This rate of loss had been expected over 40 to 50 years under the ISC strategy, which would have conserved much less habitat than is conserved under the Plan.

Extent to Which Differences Were Caused by the Plan

Trends in the amount and distribution of northern spotted owl habitat on federal lands were strongly influenced by the Plan. The system of reserves and the restriction on harvest of owl habitat through various standards and guidelines outside of reserves has done much to conserve and restore owl habitat. Clearly, the rate of loss of northern spotted owl habitat from timber harvest on federal lands has been reduced since the implementation of the Plan (see chapter 3, fig. 3-1d). About 41 percent of current owl habitat is on nonfederal lands, over which the Plan has little influence. Some influences from large reserves on federal lands have affected management of habitat on nonfederal lands, in that state and private entities have tied conservation of owl habitat on their lands to adjacent federal reserves (Pipkin 1998). Current habitat has been and will continue to be harvested faster from nonfederal lands than from federal lands.

Habitat has been lost by fires, insects and disease, and many of the lost acres are in large reserves, especially in the drier provinces with non-lethal frequent fire regimes. Active management of forests in fire-prone areas of the eastern and southern parts of the owl range to reduce risk of catastrophic losses has not been as extensive as envisioned under the Plan. To

date, the loss of owl habitat to fire, though locally important (as in the Biscuit Fire), has not been extensive rangewide (see chapter 6). Failure to implement some of the provisions for risk management, however, has increased the risk of future losses of habitat in dry provinces, and which may reduce the potential for owl persistence in affected reserves in those areas. Overall, though, the replication of reserves provides a buffer against losses to fire and other catastrophic events.

Northern spotted owl populations have continued to decline, despite the lower than expected rate of habitat loss. The rangewide rate of population decline is similar to the rate that had been observed at the start of the Plan and continues to be cause for concern. If this rate were to continue, the owl population could decline by 66 percent in 3 decades. Populations in Washington are declining faster than elsewhere, and the rate of decline has accelerated over the past 10 years. Several factors could contribute to this decline, including the lingering effects of past timber harvest, continuing logging on nonfederal land, forest succession and suppression of fire, defoliation from insects, and interactions with the barred owl. Blakesley and others (2004), in their summary of northern spotted owl demographics as part of the status review, suggested that circumstantial evidence points toward interactions with the barred owl as the most likely cause of the decline in the northern part of the owl range. They also pointed out that owl populations in the northern range may be more susceptible to prey shortages, higher energy expenditure, and more extreme weather. In support of this possibility of interactions between habitat quality and weather, Franklin and others (2000), in his California study, found that owls in territories with high quality habitat had greater survival during inclement weather than those in poor quality habitat. Available data are not sufficient to establish direct cause-and-effect

relations, but the loss of habitat in Washington during the past 10 years is not a likely cause of the higher rate of population decline there, because the rates of habitat loss in Washington are lower than rates elsewhere where owl populations have been stationary. The bottom line is that the Plan has been successful in conserving remaining owl habitat on federal lands, and the reserve system has provided for restoration and increases in habitat over time, but that the relationship of habitat to population trend has not been straightforward.

Although conservation and restoration of habitat are essential to northern spotted owl conservation, habitat protection alone may not be sufficient to conserve and restore owl populations. Other emerging threats, such as the barred owl, may cause continuing declines even though habitat conditions are otherwise sufficient to support stationary or increasing owl populations. For example, recent studies in Oregon and Washington (Kelly and others 2003) found that northern spotted owls were displaced from territories when barred owls were observed within 0.5 miles of the territory center. Species irruptions of this type are beyond the control of habitat managers and the Plan itself cannot prevent irruptions of invasive species. The redundancy built into the reserve design may yet allow for some level of coexistence of northern spotted owls and barred owls, but no agreement has been reached among experts on whether the two species will indeed coexist or whether the barred owl will eventually overcome and displace the northern spotted owl from major portions of its range. In the recent scientific evaluation of the status of the spotted owl, Gutiérrez and others (2004) described several alternative hypotheses about the results of interactions between spotted owls and barred owls:

Clearly plausible:

- Barred owls will replace the northern spotted owl throughout its range (behavioral and competitive dominance hypothesis).
- Barred owls will replace the northern spotted owl in the northern, more mesic areas of its range (moisture-dependent hypothesis).
- Barred owls and northern spotted owls will compete, with the outcome being an equilibrium favoring barred owls over spotted owls in most but not all of the present spotted owl habitat range (quasi-balanced competition hypothesis).

Plausible:

- *The barred owl will replace the northern spotted owl over much of its range, but the spotted owl will persist in some areas with management intervention (management hypothesis).*
- Barred owls will replace the northern spotted owls in the northern part of its range but the spotted owl will maintain a competitive advantage in habitats where its prey is abundant and diverse (specialist vs. generalist hypothesis).

Not plausible or not clear:

- Barred owls will replace the northern spotted owl over much of its range, but the spotted owl will persist in refugia (refugia hypothesis).
- Barred owls will replace the northern spotted owl in some habitats but not in others (habitat hypothesis based on structural elements of forest, which confer a maneuverability advantage to the smaller spotted owl).
- Barred owls will increase to a peak number, then decline or stabilize at a lower density, which will permit the continuation of spotted owls (dynamics hypothesis).
- Barred owls will replace the northern spotted owl only where weather and habitat perturbations have placed spotted owls at a competitive disadvantage (synergistic effects hypothesis).

Other emerging threats to the northern spotted owl are outside of direct control under the Plan. The West Nile Virus (the virus) arrived in the United States in 1999 and has expanded into the West. This virus is known to cause widespread mortality in wild birds, and one captive northern spotted owl is known to have died from it. Blakesley and others (2004) said that the virus could reduce population viability throughout the owl's range, but they also say that the degree to which this potential will be realized is uncertain. They point out that, on one hand, the virus may have relatively short term effects as populations develop resistance after exposure but that, on the other hand, long-lived species with relatively low annual reproductive output may not recover quickly from an outbreak. Sudden oak death, a disease caused by a fungus-like organism, is

another recent invader causing locally widespread mortality of a variety of trees, mostly in central California, but with a few in southern Oregon. This disease can kill tanoak and other tree species that provide cover and prey to the northern spotted owl, especially in the southern portions of its range where woodrats are an important part of its diet. Predicting the effects this disease will have on owl habitat is difficult, but the risk is important to recognize. I am not aware of any evidence the emergence of these new threats is a direct consequence of the Plan. Other potential risks, over which federal land managers have little control, include global warming and the rate of loss of owl habitat on nonfederal lands.

Sources of Uncertainty

Habitat status and trends—

One important accomplishment of the owl effectiveness monitoring program was production of a rangewide map of northern spotted owl habitat. Until this effort, no wall-to-wall coverage was available; existing maps covered only federal lands and were assembled from a variety of sources, including satellite imagery, professional judgment from local biologists, and other sources. The current map provides, for the first time, a consistent portrayal of the amount and distribution of owl habitat over the Plan area's full extent. The data were not ideal: there were differences in vegetation mapping between California (which was based on the CALVEG system) and Oregon/Washington (which was based on IVMP system); the two map products had to be reconciled and this led to compromises and some degradation of quality. In spite of these difficulties, the resulting map provides a fresh baseline to describe initial conditions and from which to assess changes over the Plan's first 10 years. The map was compiled from information

on forest attributes at sites where owls are known to live. The output from the habitat-suitability models is a continuous range of suitability from 0 to 100, with higher values indicating those conditions that are more typical of owl occurrences in the Plan area. Habitat suitability has great utility in describing and ranking owl habitat. For example, in an independent effort McComb and others (2002) built an owl habitat suitability map for the Coast Ranges of Oregon and found that owl occurrence could be predicted with a classification success of 75 percent. Davis and Lint (in press) used a cross-validation process and demonstrated that their habitat suitability maps were highly reliable (see their paper for details). In these cases, owl occurrence not owl demographic performance was used in model building. The veracity of this relation between animal occurrence and habitat quality is the subject of much debate (see Van Horne 1983), but I would prefer to have some measure of fitness in relation to forest condition, and much uncertainty exists about what habitat suitability can tell us. In addition, the habitat maps are built on a set of vegetation attributes that were, in turn, derived from models—models relating spectral signatures to forest cover with their own inherent uncertainties.

The habitat suitability maps show a full range of scores, from 0 to 100. To ease communication about results from the map, it is often useful to summarize amount of land area that exceed some cutpoint for suitability and tallying all sites that exceed that cutpoint. Davis and Lint (in press) chose to summarize areas with scores greater than 41, based on the range generally associated with 90 percent of owl sites, to define a range that is most similar to areas where owls were known to be. This criterion facilitated discussion of amounts of habitat, but other criteria could have been chosen. Any other criterion will result in a different total. The amount of baseline habitat estimated is thus not an absolute quantity but rather depends on the choice of cutpoint.

Davis and Lint, preferred to tabulate the distribution of acres for the full range of suitability scores. Future monitoring will rely on evaluating changes in the frequency distribution of all suitability scores, not just the acres with the highest scores.

Estimating rates of change in habitat over the past 10 years also carries much uncertainty.

Ideally, agency records could be used to map all timber harvest acres, but the records are incomplete. Instead, harvest was estimated by comparing satellite images to detect change. This comparison could detect only regeneration harvest; thinning and other partial harvest that might affect owl habitat could not be mapped. Change detection was also used to locate stand-replacing fires. Again, fire that resulted in partial loss of canopy was more poorly mapped (see Davis and Lint, in press; Moeur and others, in press; for a more thorough discussion). According to Davis and Lint (in press), approximately 13,200 wildfires were recorded on federal lands (in the 10 provinces where they mapped owl habitat) from 1994 to 2002. Using these data, around 1.7 million acres of federal land (USFS, NPS and BLM) burned within the range of the northern spotted owl. Stand-replacing wildfire data (Moeur and others, in press) suggest that about 230,000 acres were burned with stand-replacing severity, or about 14 percent of the total area burned. The remaining 86 percent of the area burned at lower intensities and severities across all habitat suitabilities and Davis and Lint were unable to describe the effect this may have had on owl habitat.

Habitat regrowth was estimated by Moeur and others from remeasurement of inventory plots, and summarized by tree diameter class. Diameter was only one of several vegetation attributes used to model owl habitat, so the crosswalk between diameter classes and owl suitability classes

was highly uncertain. This uncertainty makes inferences about regrowth of owl habitat from transition rates between diameter classes problematic. Davis and Lint (in press) found a strong correlation between stand age and habitat suitability score. They found that suitability scores >40 can be achieved in stands as young as 30 years in the Coast Range of Oregon and 50 years in Oregon Western Cascades. Thus, habitat suitability scores >40 can be achieved in older clearcut harvest plantations. Irwin and others (2000) documented owl nesting in stands as young as 45 years in western Cascades of Oregon. This probably accounts for some of the 41 percent of habitat on nonfederal lands, which is likely at this lower end of the suitability scale.

Habitat conditions were expected to improve over time as currently unsuitable forest matures and gains attributes to support nesting, roosting, and foraging behavior of the owl. A high potential exists for loss of habitat, especially in the drier portions of the owl's range (but to varying extent throughout the owl range), because of the risk of uncharacteristically large and severe wildfires. Whether appropriate fuels treatment activities will be done and whether such actions will successfully reduce risk of loss of habitat is highly uncertain.

Population status and trends—

Estimates of northern spotted owl population trends were based on a sample of over 10,000 marked owls captured in study areas that encompassed more than 12 percent of the owl's range. Because of this robust sample, estimates of survival, fecundity, and population change were quite precise. I have confidence that the estimates reflect true population trends from 1990 to 2003, but I am not confident in extending these trends into the future. Doing so requires the assumption that vital rates over future years do not change from those observed to date. This assumption is

unlikely to hold because habitat conditions will change over time, and because emerging threats such as the barred owl, West Nile Virus, and sudden oak death may also alter these rates. So will climate change, both short-term (changes caused by the Pacific Decadal Oscillation) and long-term, could have direct and indirect effects on the owl and its prey, increasing uncertainty of population projections.

Are Plan assumptions Still Valid?

A fundamental Plan assumption was that large, contiguous blocks of habitat are necessary to support a viable population of owls. The reserve system was designed to support large populations of owls and reserves were spaced close enough to permit recolonization after local disturbance. The size and spacing of these reserves was thus designed to reduce risk of long term extirpation. The basic science behind this design has not changed: no new evidence suggests that large blocks of habitat are not critical to the persistence of the owl. Large blocks of habitat, while necessary, may not be sufficient to sustain owl numbers if owl mortality rates increase because of the barred owl and other emerging threats. I also note that large blocks of habitat do not always equate to contiguous blocks of old forest. In southern portions of the owl's range, where woodrats are a primary prey, foraging habitat includes brushy cutover or burned areas that support prey. In these areas, large blocks of habitat are a mixture of old forest in juxtaposition with patches of shrub/small tree cover (Olson and others 2004). The importance of this type of habitat was recognized in the Plan, but much uncertainty exists in how much of it will be retained over the long term in large reserves.

The Plan also assumed that land areas between large reserves, the Matrix (including Riparian Reserves along permanent and intermittent streams), would function primarily to support owl dispersal. In practice, more owl habitat is in the Matrix than was expected in the Plan. Timber harvesting has been reduced from the expected rate, and there are legal challenges, reduced industry capacity, and low support to cutting older forest in the Matrix, resulting in a likely delay in decline of owls using habitat in Matrix lands.

Silvicultural treatments were assumed to be implemented to reduce fuels and manage risk of stand-replacing fire in dry portions of the owl's range. Such treatments were not done to the extent that may be required and, as a result, the risk of catastrophic loss of habitat in affected reserves may be greater than was assumed in the Plan's design in these areas (see chapter 6). I reiterate, though, that the redundancy built into the Plan through multiple reserves serves as a strong buffer against such losses.

Marbled Murrelet

The marbled murrelet is a small seabird of the family Alcidae whose summer distribution along the Pacific Coast of North America extends from the Aleutian Islands of Alaska to Santa Cruz, California. It forages primarily on small fish in the near-shore (0-2 miles) marine environment. Unlike other alcids, which nest in colonies on the ground or in burrows at the marine-terrestrial interface, marbled murrelets nest solitarily and most often in large trees in coniferous forests, traveling up to 50 miles inland to reach suitable habitat (most often < 25 miles). Because marbled murrelets depend on marine conditions for foraging and resting and on forests for nesting, both marine and forest conditions can limit murrelet numbers. Because of population

declines attributed to loss of mature and old-growth forest from harvesting, low recruitment of young, and mortality at sea, this species was federally listed as Threatened in Washington, Oregon, and California in 1992 (USFWS 1997) and listed as Threatened in British Columbia (Rodway 1990). Because of the murrelet's association with late-successional and old-growth forests and because of its listed status, conservation of the marbled murrelet was an explicit goal in the design of the Plan.

The Plan is conservative about marbled murrelet habitat. The system of reserves was not designed, as it was for the northern spotted owl, with specific goals for the number and spacing of clusters of birds. Rather, the system of Congressionally Reserved lands and Late Successional Reserves would encompass a high proportion (about 2.0 million acres of existing murrelet nesting habitat out of a total of 2.6 million acres) of habitat thought to exist on federal lands. In addition, murrelet surveys would be conducted before harvest on any other lands in the murrelet range. If a survey showed likely nesting, then all contiguous existing and recruitment habitat (defined as stands that could become nesting habitat within 25 years) within a 0.5 mile radius would be protected. These occupied sites became small reserves, denoted as LSR3, and would be managed to retain and restore nesting habitat.

What was Expected Under the Plan?

The stated objective of the Plan was to maintain, restore, or both nesting habitat conditions that would provide for viability of murrelet populations, well-distributed along their current range on federal lands (FEMAT 1993: iv). The expectation was that the Plan "...would eventually provide substantially more suitable habitat for marbled murrelets than currently [**that is, at the time the**

Plan was implemented] exists on federal lands” (USDA and USDI 1994a). The FEMAT used an expert panel to assess the likelihood that habitat on federal lands would support stationary and well-distributed populations of the marbled murrelet. Following the methods described above for the owl, the murrelet expert panel assigned an 80 percent likelihood that habitat would be of sufficient quality, distribution, and abundance to allow the murrelet population to stabilize, well-distributed across federal lands over the next 100 years (Outcome A) under Option 9, which eventually was adopted (with modifications) as the Plan. The panel assigned a 20-percent likelihood for Outcome B, under which habitat would be sufficient to allow the murrelet population to stabilize but with significant gaps in the historical distribution that could cause some limitation in interactions among local populations. The panel assigned no likelihood of Outcomes C or D. Thus, the panel’s assessment was that the likelihood was high that habitat conditions on federal lands would allow the marbled murrelet population to stabilize and be well-distributed throughout its range. In recognition of the major influence of marine conditions on population viability, however, including mortality from oil spills and gill netting, and considering the potentially important role of nonfederal lands, the murrelet panel assigned a second set of ratings considering the cumulative effects of all major factors. The murrelet panel concluded that the likelihood that the murrelet population on federal lands would be stationary and well-distributed was between 50 and 75 percent. The higher rating was meant to indicate the degree of protection conferred by habitat conditions on federal lands, assuming all other factors were not limiting; the lower rating from the cumulative effects analysis was an attempt to indicate the greater uncertainty in murrelet persistence given the importance of other factors beyond federal habitat.

Neither FEMAT nor the FSEIS nor the subsequent monitoring plan for the murrelet (Madsen and others 1999) provide quantitative descriptions of expected murrelet population trends or nesting habitat trends over time that could be used to assess Plan performance over the past 10 years. We do have some more qualitative descriptions, however:

- The amount of murrelet nesting habitat has declined over the past 50 years, primarily because of timber harvesting (Perry 1995).
- Murrelet populations are likely to have declined as well, largely in response to loss of nesting habitat (Ralph and others 1995).
- Demographic projection models estimated at the time the Plan was initiated suggested a population decline of 4 to 7 percent per year from 1990 to 1995 (Beissinger 1995).
- Because murrelets have naturally low reproductive rates, population recovery will be slow, on the order of a maximum of 3 percent per year (USFWS 1997).
- No destruction of nesting habitat surrounding active murrelet nesting sites will be knowingly done on federal lands.
- Catastrophic and stochastic events that decrease the quality or quantity of nesting habitat would affect nesting habitat at unknown rates.
- Over the long term, the amount of nesting habitat will increase in reserves as unsuitable habitat matures; Late Successional Reserves will provide large contiguous blocks of nesting habitat with increased interior habitat.
- Rates of nest depredation would decrease as the amount of interior nesting habitat increases in reserves.

- In the short term (< 50 years), the availability of nesting habitat may remain stable or decline from losses from fire and other natural disturbances.
- The rate of increase in the amount of nesting habitat will be slow because trees do not develop structures suitable to support nests until they are large and old, often 150 or more years (USDA and USDI 1994a).
- Habitat management on nonfederal lands will affect viability of marbled murrelets on federal lands.
- Physical and biological processes in the marine environment, which operate at multiple temporal and spatial scales, also affect short- and long-term population trends of marbled murrelet, independent of nesting habitat quantity or quality.

McShane and others (2004) developed a population model to predict population change in each of five conservation zones comprising the Plan area. Their model, which used annual adult survival estimates obtained from detailed mark-recapture studies in British Columbia (the only such data available) and fecundity estimates from observing juveniles at sea or telemetry studies, predicted annual rates of decline varying from 3 to 5 percent per year over the first 20 years of their simulations in Murrelet Conservation zones 1 through 5.² Rates of decline were generally greater going from north (zones 1 and 2) to south (zone 5). These predictions are in line with those of Beissinger (1995). These models do not directly account for amount of nesting habitat, and so model projections do not respond to expected habitat trends.

What has Happened and did Expectations Differ from Observations?

Baseline habitat—

When the Plan was developed, no consistent map of marbled murrelet nesting habitat was available. For purposes of the Plan, murrelet nesting habitat was assumed to be late-successional forest with much the same characteristics as northern spotted owl habitat. Therefore, the existing map of spotted owl habitat, which was itself a mosaic derived from compilations of local maps based on agency judgment, classified satellite imagery, and existing inventory maps, was constrained to the range of the murrelet and used as a proxy for murrelet nesting habitat. No estimate or map of habitat on nonfederal land was available. The marbled murrelet effectiveness monitoring group developed a new map, using a consistent vegetation base (based on vegetation data from CALVEG and the Interagency Vegetation Mapping Project, see Moeur and others in press), across all ownerships throughout the range of the murrelet (Raphael and others, press). This habitat classification was based on estimates of patch size, conifer cover, quadratic mean tree diameter, canopy structure, slope, aspect, and distance from coast. Raphael et al developed a habitat suitability model in much the same manner as described above for owl habitat. Under this model, habitat suitability ranges along a scale from 0 (least suitable) to 100 (most suitable). Raphael and others used a cutoff of suitability >60 to portray potential nesting habitat in tables and maps. The total amount of potential nesting habitat estimated from this new map was 1.9 million acres on federal land within Marbled Murrelet Zone 1 (the zone closer to the west coast in which most murrelets occur). The estimate of habitat on federal land from the FSEIS was 2.6 million acres in murrelet zones 1 and 2 combined (there was no separate estimate for zone 1 alone). I expected differences in estimates as the new map was derived from a satellite-based suitability model and because Raphael and others defined an upper elevation limit for murrelet nesting, and some nesting habitat considered by the FSEIS may have been above that limit.

About 28 percent of acres capable of supporting murrelet habitat is on federally administered lands in the murrelet range portion of the Plan area (of 18.0 million acres of federal and nonfederal habitat-capable land); federal lands support 42 percent of nesting habitat. About 2.1 million acres (52 percent) of murrelet nesting habitat is on nonfederal lands (Raphael and others, in press). The contribution from nonfederal land varies: in Washington, 77 percent; in Oregon, 55 percent; and in California, 47 percent (fig. 7-4). On federal lands, about 75 percent of habitat-capable land is in reserved land use allocations and 81 percent of nesting habitat is in those allocations (fig. 7-5). In Washington, the amount of nesting habitat in reserves is 93 percent; in Oregon, 76 percent; and in California, 71 percent. The Plan seems to have successfully captured most of the existing nesting habitat in the reserve system. The FSEIS estimated that 86 percent of murrelet nesting habitat would be in reserves. The reserve system includes about 63,000 acres of habitat-capable forest in LSR3s and these small reserves contain about 21,000 acres of suitable habitat. I conclude that the Plan has successfully encompassed a majority of murrelet nesting habitat within its reserve system and that additional occupied habitat outside the large reserves has been designated and reserved.

Habitat losses—

The intent of the Plan was to conserve most of the remaining murrelet nesting habitat and to prevent the subsequent loss of any habitat occupied by nesting birds, wherever that habitat was on federal lands. The amount of habitat was expected to increase over time, but the rate of increase would be very slow and changes might not be observed for many decades. In the

meantime, some unoccupied habitat would be lost from timber harvest, and some losses might be caused by wildfire and other disturbances.

The observed trends are in line with these expectations. Raphael and others (in press), based on analysis of satellite imagery and change detection methods (see Moeur and others, in press) estimated losses of 54,900 acres of nesting habitat on federal lands over the past 10 years, mostly from fire, and most of that in one event, the Biscuit Fire. Losses from timber harvest totaled 3,800 acres, 74 percent of which was outside of reserves. Losses to fire and other stand-replacing events totaled 51,000 acres, and 93 percent was in reserves. Total losses represent 2.3 percent of nesting habitat over the 10 years, or a loss of 0.23 percent per year. Rates of loss have been much greater on nonfederal lands: Raphael and others (in press) estimate that over 150,000 acres of nesting habitat, or about 10 percent, has been lost because of timber harvest over the past 10 years.

As part of the status review for the murrelet, McShane and others (2004), compiled agency records (almost all from federal lands) to estimate losses to harvest and fire, and developed an independent estimate of amounts and losses of murrelet nesting habitat. McShane and others estimated total losses from 1992 to 2003 of 22,400 acres, 5,400 from harvest and 17,000 from fire and windstorms. They estimated a total of 2.2 million acres of suitable habitat on all ownerships; losses represent 1.1 percent of that amount, or 0.11 percent per year. The Raphael and others and McShane and others estimates apply to all habitat, whether occupied or not. I have no estimate of the loss of occupied habitat, so I cannot say whether the Plan objective of no loss of occupied habitat from timber harvest was met. Raphael and others and McShane and

others differ because of the sources of data used and the records available in each case. Because the Raphael and others analysis is a more thorough evaluation of the entire murrelet range and uses change-detection methods, I believe it is more complete than the McShane and others data.

Habitat increases—

One Plan expectation was a gradual increase in the amount of suitable habitat as forests mature. Some evidence showed that the amount of forest with large (>20 in) diameter trees has increased over the first 10 years of the Plan, based on analyses of inventory plots on national forest lands in the murrelet range (M. Moeur, unpublished data). Moeur tallied the distribution of plots by mean tree diameter during two remeasurement cycles, averaging 3.8 years apart. She estimated a net annual increase of the largest tree diameter class (>30 inches) of 0.4 percent per year over the past decade. I do not know how much of this increase represents suitable nesting habitat. Certainly, not all of it does, because nesting platforms (the key attribute defining suitable nesting habitat) do not generally form until trees reach diameters of 40 inches or more (Raphael 2004). Further work will be needed to verify how much of the increase actually has attributes of suitable habitat.

Population trends—

Murrelet populations were thought to be declining at the start of the Plan and I expected these declines to continue until habitat recovered from previous losses. The marbled murrelet effectiveness monitoring group designed a coordinated sampling protocol and obtained population estimates starting in 2000; yearly estimates have continued and are reported up to year 2003 (Miller and others, in press). The total estimated population has averaged about 18,200

birds over the four years of survey. Estimates vary by conservation zone (fig. 7-6), with the largest population in Zone 1 (Puget Sound, Washington) and the smallest in Zone 5 (north-central California). Population size did not show a downward trend during the four years of study; the numbers were relatively stationary. Given the confidence intervals around the mean population estimates each year, Miller and others (in press) computed that 7 years of survey would be required to detect a 5 percent annual decline with a power of 80 percent. I conclude little evidence exists of the expected decline in murrelet numbers, but I recognize that more years of survey will be needed to confirm this conclusion with greater confidence.

Extent to Which Differences Were Caused by the Plan

Habitat status and trend—

The Plan played a pivotal role in the fate of marbled murrelet habitat on federal lands. The Plan has been highly successful in conserving existing murrelet nesting habitat, and little habitat has been lost from timber harvest. Some loss of habitat, especially in reserves, was caused by fire. Loss of murrelet habitat from catastrophic events will always be a risk, and such losses were expected. The Plan has less control over risk to such losses, except to the extent that active management in fire-prone areas might reduce risk by managing fuel. One caution need to be recognized: managing forest cover to reduce fire risk could also lead to better habitat for corvids (nest predators); silvicultural practices may need to be fine tuned to ensure they do not inadvertently impair nesting success of murrelets through increasing the rate of nest depredation.

The fate of habitat on nonfederal lands is beyond the scope of the Plan, and 72 percent of habitat-capable forest is in state or private ownership with 52 percent of murrelet nesting habitat is on these nonfederal lands. The rate of harvest on nonfederal lands (1.2 percent per year) has been far more rapid than that on federal lands (0.1 percent per year).

Raphael and others (in press) found evidence of increase in the area occupied by forests with large trees (>30 inches diameter) on federal lands. This increase is consistent with Plan expectations; if any of this increase contributes additional nesting habitat, however, it would have been more quickly than was expected. The large reserves included recruitment habitat at the start of the Plan, and some of that habitat may not require many years to meet the attributes of suitable nesting habitat.

Population trends—

Marbled murrelet populations are affected by a variety of factors, only some of which are under the Plan's direct influence. The Plan most directly affects populations through its provisions for conservation and restoration of nesting habitat, but even then the Plan's influence extends only to the federal lands. The Plan has no influence on marine conditions (including marine food sources) or sources of mortality at sea such as oil spills and gill netting. Therefore, it will be more difficult to relate changes in marbled murrelet populations to land management under the Plan. With the Plan conserving habitat exactly as expected, murrelet populations could still fall because of adverse marine conditions or because of habitat loss on nonfederal lands. Despite this uncertainty, evidence suggests that inland habitat conditions are the major driver setting murrelet population size. This point is illustrated in figure 7-7, which shows a very strong correlation with

the total amount of habitat and size of adjacent murrelet population for segments of the murrelet range. Habitat seems to be the primary driver, with marine conditions possibly contributing to residual variation along the coast.

Sources of Uncertainty

Habitat status and trends—

Sources of uncertainty in estimating the amount and distribution of nesting habitat of the marbled murrelet are very similar to those cited for the owl. But one additional source is unique to the marbled murrelet. Because murrelet nesting behavior is so cryptic, biologists have found very few actual nests of the species. Habitat models for the spotted owl were built from attributes of a large sample of known owl nest sites. For the murrelet, biologists rely on locations of “occupied behaviors” to infer nesting activity. Occupied behaviors are observations of murrelets flying into the canopy or circling very close above the canopy. These behaviors are presumed to be associated with nesting, but nesting is rarely verified. Thus sites in which occupied behaviors are observed may not be true nest sites. To the extent that false positives are included in the murrelet database used to build models, these models may be less accurate than if all locations were based on verified nests. Furthermore, occupied behaviors are not observed at every visit to a site; a finite likelihood exists of failing to detect occupied behaviors even if the site is occupied. A specific protocol (Evans Mack and others 2003) sets the numbers of visits required to have a high likelihood (set at 0.95) of observing occupied behavior at an occupied site. Under this protocol, a 5 percent chance of failing to detect occupied behavior exists, so a small number of sites might be mistakenly classified as unoccupied and released for timber harvest. A more

reliable modeling solution would be to conduct intensive research to identify known nest sites and then to build models from training sites that represent actual murrelet nests.

Uncertainty also exists in the geographic distribution of the marbled murrelet. The FEMAT designated two zones: Zone 1 formed the area closer to the marine environment, and Zone 2 was an outer area along the eastern fringe of the species' range. Populations were assumed to be more abundant in Zone 1. More recent surveys have led to suggestions for substantial local contractions of Zone 2, and possibly even Zone 1, especially in northern California and southern Oregon (Alegria and others 2002, Hunter and others 1998, Schmidt and others 2000). Agencies in those areas have redefined the eastern boundary, where surveys for murrelets are required prior to timber harvest, bringing it farther to the west to match survey results. This revised boundary has not been formally implemented in the Plan databases; to date this revision only applies to survey requirements. This strategy adds uncertainty in the calculation status of habitat to the extent that acres classified as habitat may actually fall outside the revised species range.

Population status and trends—

We have only four years of murrelet data from which to assess population trend. Error estimates around each year's population estimate are fairly large, so it will take 7 or more years before one can reliably say whether the population is stationary, increasing, or decreasing. The data collected so far seem to indicate a relatively stationary population, which is at odds with the prediction, calculated from demographic models that predict the population should be declining (McShane and others 2004). A major source of uncertainty is whether the murrelet population is closed or open. That is, existing population models assume there is little or no recruitment of

either adults or juveniles from outside the study population. The local population may be declining, but populations may be being subsidized by immigrants, perhaps from Alaska or British Columbia where the birds are more numerous. Recruitment of birds from outside the local range has been proposed as the most likely explanation for observed stationary murrelet population trends in central California, despite models that suggest a decline (Peery 2004).

Future population trends are also difficult to predict because of uncertainties in the timing and extent of risk factors. Catastrophic loss of habitat from uncharacteristically severe wildfire is an ever-present risk in portions of the range. Populations at sea are subject to risk from large oil spills. Changes in ocean currents can have profound effects on forage fish leading to starvation or breeding inhibition, as has been observed in other seabird populations (for example, Montevecchi and Myers 1997). Emerging threats exist from the West Nile Virus, which could cause direct mortality to nesting birds, but the virus could also have indirect beneficial effects. The virus is documented to kill jays, crows, and ravens, and mortality of these birds may increase nest success of murrelets by reducing nest depredation.

Are Plan Assumptions Still Valid?

The fundamental assumption of the Plan was that the rate of loss of murrelet habitat in reserves would slow or stop and that unsuitable habitat would recover. Available data support this assumption and show that rates of loss are low and that forest stands in reserves are on a trajectory toward higher habitat suitability. Conservation and restoration of murrelet nesting habitat is essential to population viability of the species.

Although federal habitat protection is essential to murrelet viability, it may not be sufficient, given the cumulative effects of other influences on population viability. Scientists assumed that murrelet viability depended on a variety of factors, many of which are not under the control or influence of the Plan. This assumption still holds. Habitat loss on nonfederal lands, marine conditions, and threats from disease, oil spills, and gill-netting could reduce the likelihood of population viability despite the habitat protections built into the Plan.

The requirement for preproject surveys was assumed to prevent the loss of any occupied sites from timber harvest. I was not able to test this assumption, because I have no way to assess whether sites were classified as unoccupied when they might actually have been occupied. I can say that sites classified as occupied were, in fact, set aside and managed as reserves.

Past timber harvest was assumed to have lingering effects on murrelet carrying capacity and nesting success. I am aware of no new data to challenge this assumption. Recent research shows that murrelet population size is reduced as habitat is lost, and that birds do not pack into remaining suitable habitat (Burger 2001, Raphael 2002a). Predator densities and rates of nest depredation are higher in areas with a variety of tree ages, so nest success is reduced in areas intermixed with young tree/brush habitats (Luginbuhl and others 2001).

A major premise of the Plan is that large reserves will support more murrelets, eventually leading to stationary or increasing populations. Nest depredation seems to be a major limiting factor on marbled murrelet populations. Over half of the known murrelet nests whose fate has been

determined failed because eggs or chicks were lost to predators, primarily jays, crows, and ravens (Manley and Nelson 1999). Recent research suggests that predator numbers are high in old-growth forests, such as those expected to develop in Plan reserves (Marzluff and others 2000, Raphael and others 2002b). Habitat fragmentation was assumed to decline as young patches within reserves matured, creating more contiguous canopy cover, and the rates of nest predation would decrease as forests became less fragmented. More recent evidence suggests that rates of nest depredation may be just as high in contiguous forest as in fragmented stands. Murrelet populations may not grow at the rate predicted from recovery of nesting habitat in reserves because nest depredation could suppress successful reproduction. We lack understanding of the full suite of factors that affect nest success, which increases uncertainty about the relations between amounts of habitat and murrelet populations.

Summary Considerations

Importance of Considering Cumulative Effects

Wildlife population trends reflect the cumulative effects of multiple interacting factors. Habitat conditions on federal lands are but one of those factors, albeit the one over which the Plan has most direct influence. Monitoring both habitat trends and population trends is of value: monitoring habitat trends tells managers how well the Plan is meeting its primary objectives; monitoring population trends tells managers if the Plan is having the desired effects. Ideally, population trend will track habitat trend, but we may observe diverging trends, as we have in the case of the northern spotted owl. In such cases, we can dig deeper to discover whether our understanding of habitat relationships is mistaken or whether other, perhaps unmeasured, factors

are driving population trends. What we can say with confidence is that the amount of habitat will set the carrying capacity for wildlife populations. Carrying capacity is a measure of the potential population size that can be supported by a given amount and distribution of suitable habitat. The actual population may be lower than the carrying capacity from a variety of other factors such as hostile weather, interactions with other species, habitat conditions outside of the planning area, disease, or other factors that might depress a population. Observing a declining population in the face of habitat conservation does not mean habitat is not important or that habitat conservation is not important. It means we have to look at options to manage some of the other factors that might be driving the population trend. Until we have more robust models of wildlife habitat relationships, including these other factors, it will be essential to continue monitoring both population and habitat trends to evaluate how well the Plan is meeting its intended objectives.

Efficacy of Large Reserves for Conservation

A central tenet of the Plan was that the system of large, late-successional reserves would largely suffice to provide for species and biodiversity components associated with late-successional and old-growth forest ecosystems. I have found that, to an extent, this is likely true. However, the degree to which late-successional reserves—along with the set of other Plan land allocations (e.g., riparian reserves in matrix lands)—suffice varies considerably by species. It also likely varies by the specific locations chosen for the late-successional reserves—such as whether they happen to intersect sites of particularly suitable habitat, and if they happen to contain microenvironmental conditions and specific habitat elements used and selected by those species. Older forest and habitat are not synonymous. For example, I described the importance of shrubby, early-seral vegetation in juxtaposition with older forest as foraging habitat for the northern spotted owl in

the southern part of the owl range. Reserves without such habitat may not function to support owls in the future if this shrubby component is not maintained as forests mature. Having large reserves, in which large expanses of old forest provide nesting habitat for owls and murrelets, and in which fire and other natural disturbances can create desired early-seral conditions for owl foraging habitat, remains a critical strategy.

One of the management dilemmas is that habitat conditions differ among species. Creating shrubby foraging habitat will be good for the northern spotted owl, but such habitat will also be good for jays and crows, which depredate nests of the marbled murrelet. In this case, what is good for the owl may be bad for the murrelet.

Efficacy of Smaller Designated Reserves

The designation of smaller reserves around owl activity centers (LSR4s) and around occupied murrelet sites (LSR3s) requires continuing survey effort to locate the birds (in the case of the LSR3s), and reduces opportunities for timber harvest in the matrix. I believe an effort could be undertaken to re-evaluate the efficacy of these smaller reserves in light of current habitat information and population trends. I suspect it would be difficult to justify removing the provisions for spotted owls in light of their continuing population decline. At a future date, if population trends appear more stationary, these reserve designations could be revised. In the case of the murrelet, there may be an earlier opportunity to revise the LSR3 designations if population trends remain stationary and habitat continues to increase in the larger reserves. A note of caution: although the LSR3s and LSR4s were established around murrelet and owl activity centers, they were also placed on the landscape to provide smaller refugia for other species

associated with older forest, not exclusively to support murrelets and owls. The owl activity centers were convenient objects to use in directing the field offices to place small blocks of older forest on the landscape. Even when they are no longer occupied by spotted owls, they still remain as protected patches of older forest, so regardless of their efficacy for owls they would still have conservation value. In essence, the LSR3s and LSR4s were built around owls and murrelets, but their function extends beyond those two species.

The Plan remains the boldest effort ever undertaken by federal agencies to meet large scale biodiversity objectives. As part of this broad biodiversity objective, the Plan had an objective to provide habitat conditions that would support viable populations of the owl and the murrelet. In the short-term, the objective for owls and murrelets was to conserve much of the best remaining habitat. The Plan has been quite successful in meeting this objective. The Plan also has a long term objective: create system of reserves containing desired sizes and distributions of large blocks of suitable habitat. Evidence suggests that habitat trends are on course toward this objective, but many more decades will be needed to judge the Plan's success. I have shown that the Plan has been remarkably successful in conserving habitat over its first 10 years of implementation, but much work remains. Owl numbers continue to decline. Time will tell if the Plan will fully succeed.

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Figure List

Figure 7-1—Distribution of northern spotted owl habitat on federal and nonfederal lands compared to amounts of habitat-capable forest land in the Plan area (after Davis and Lint, in press).

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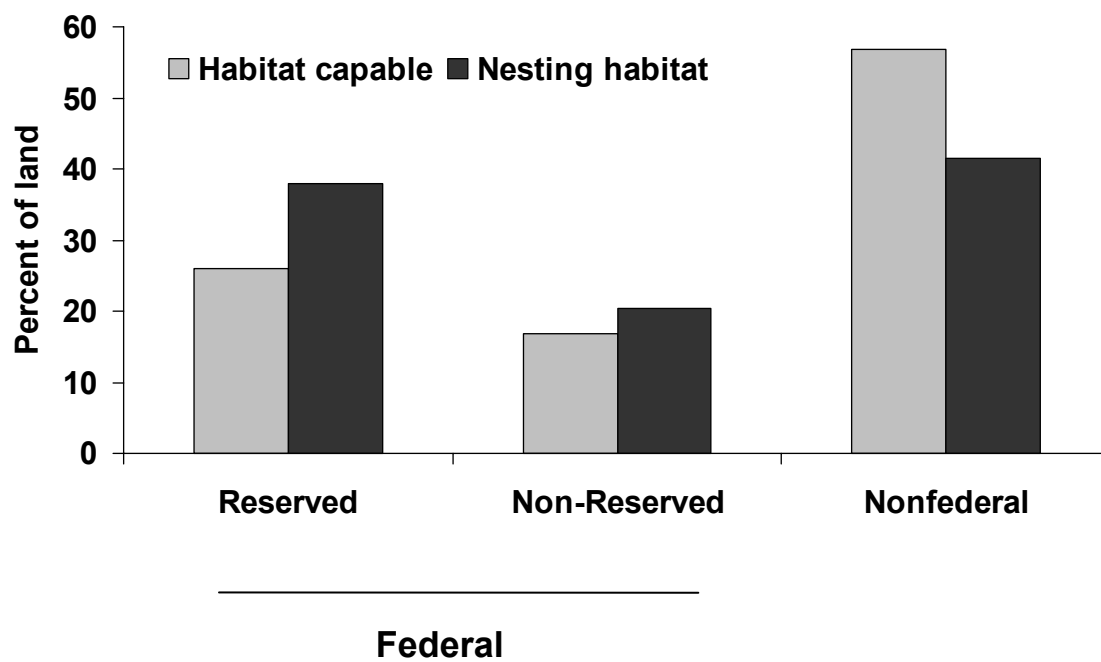
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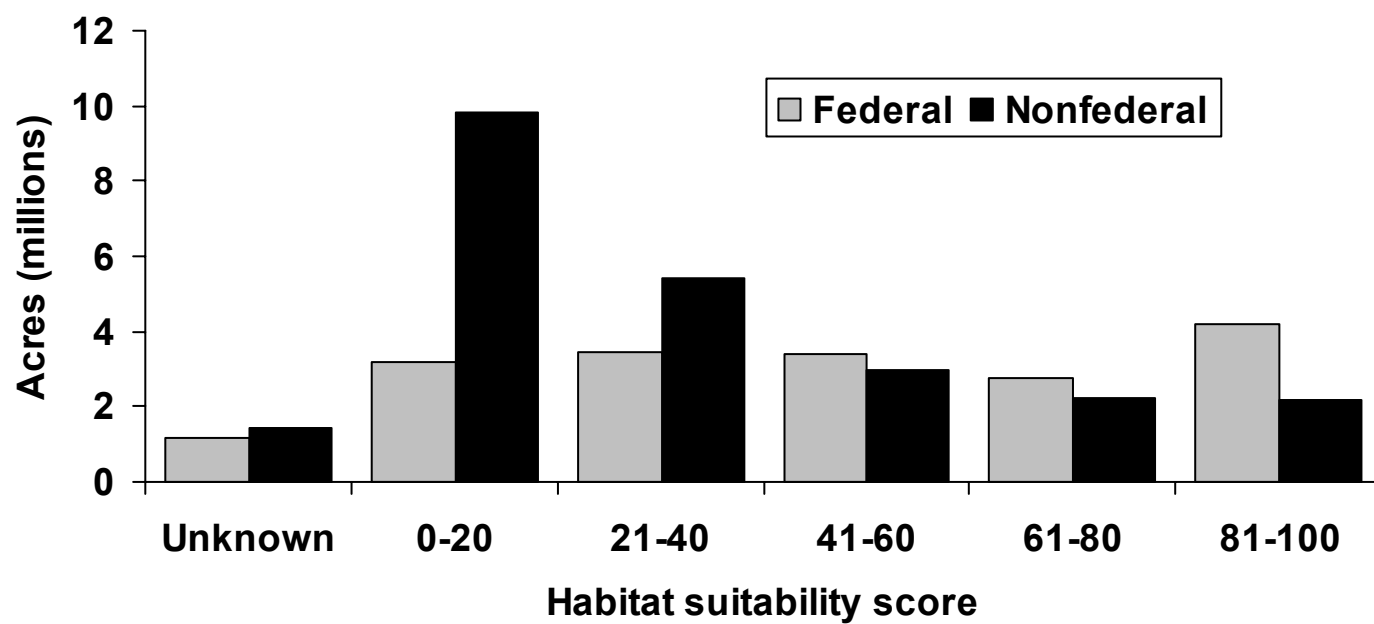
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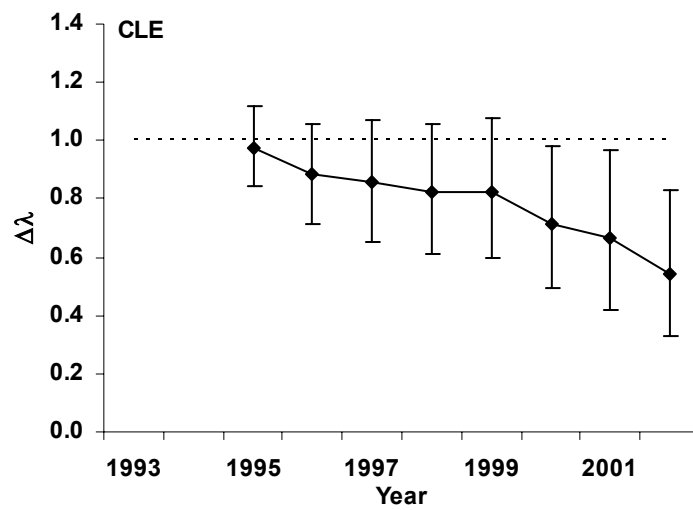
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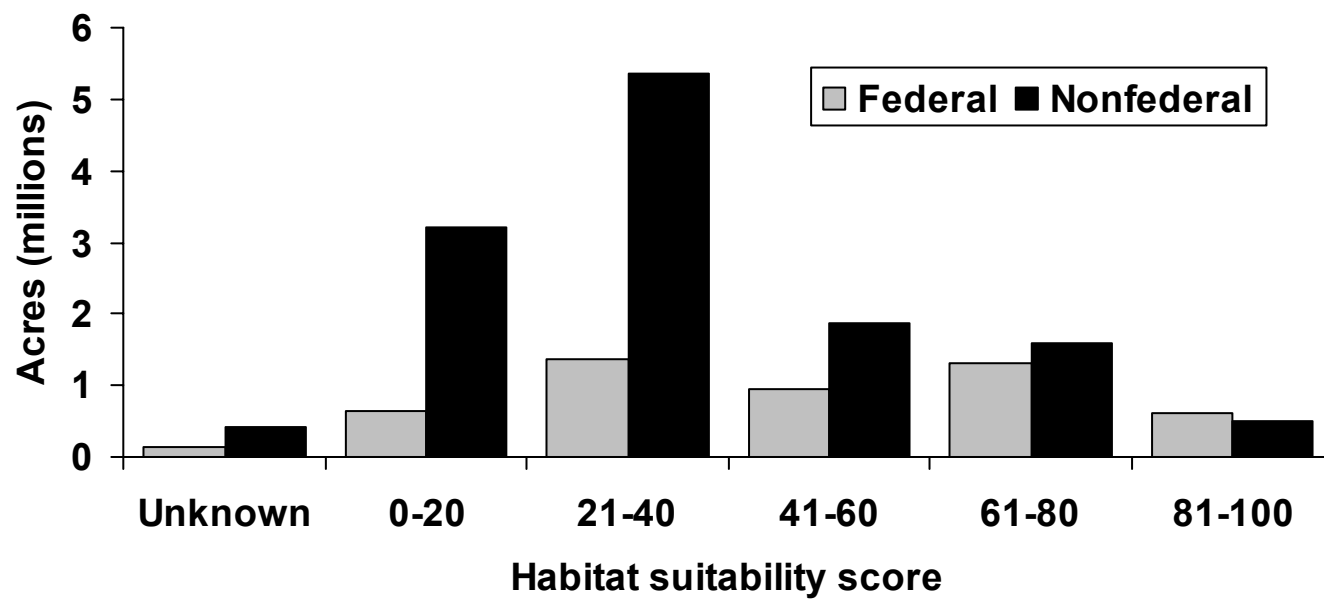
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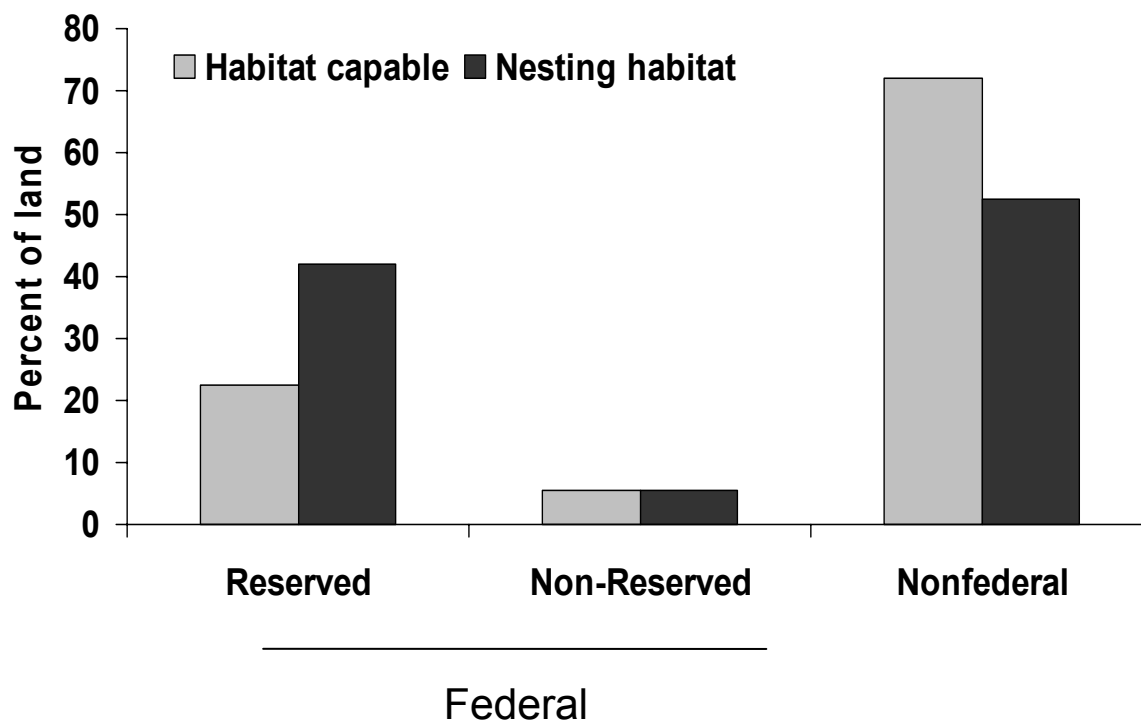
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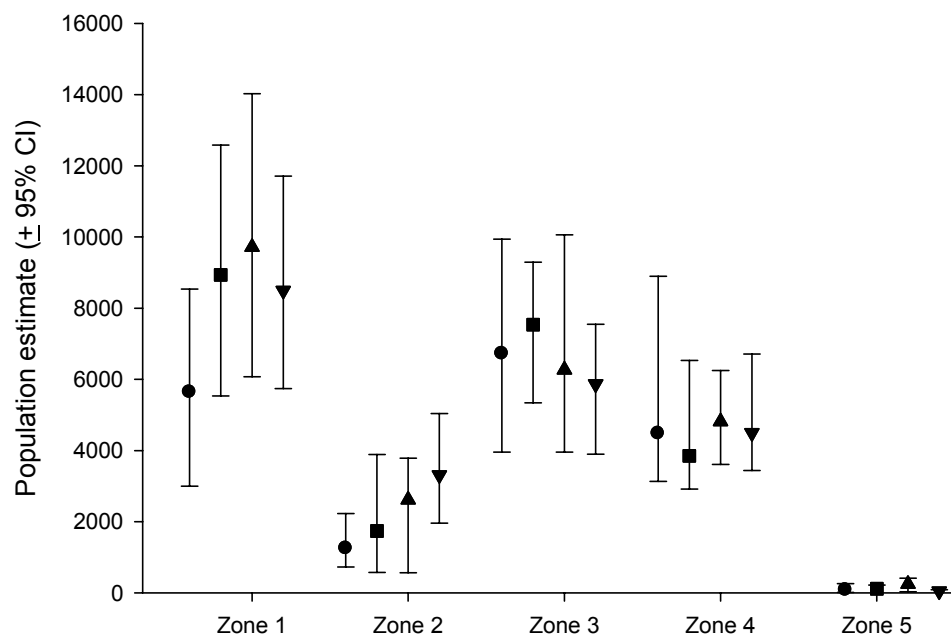


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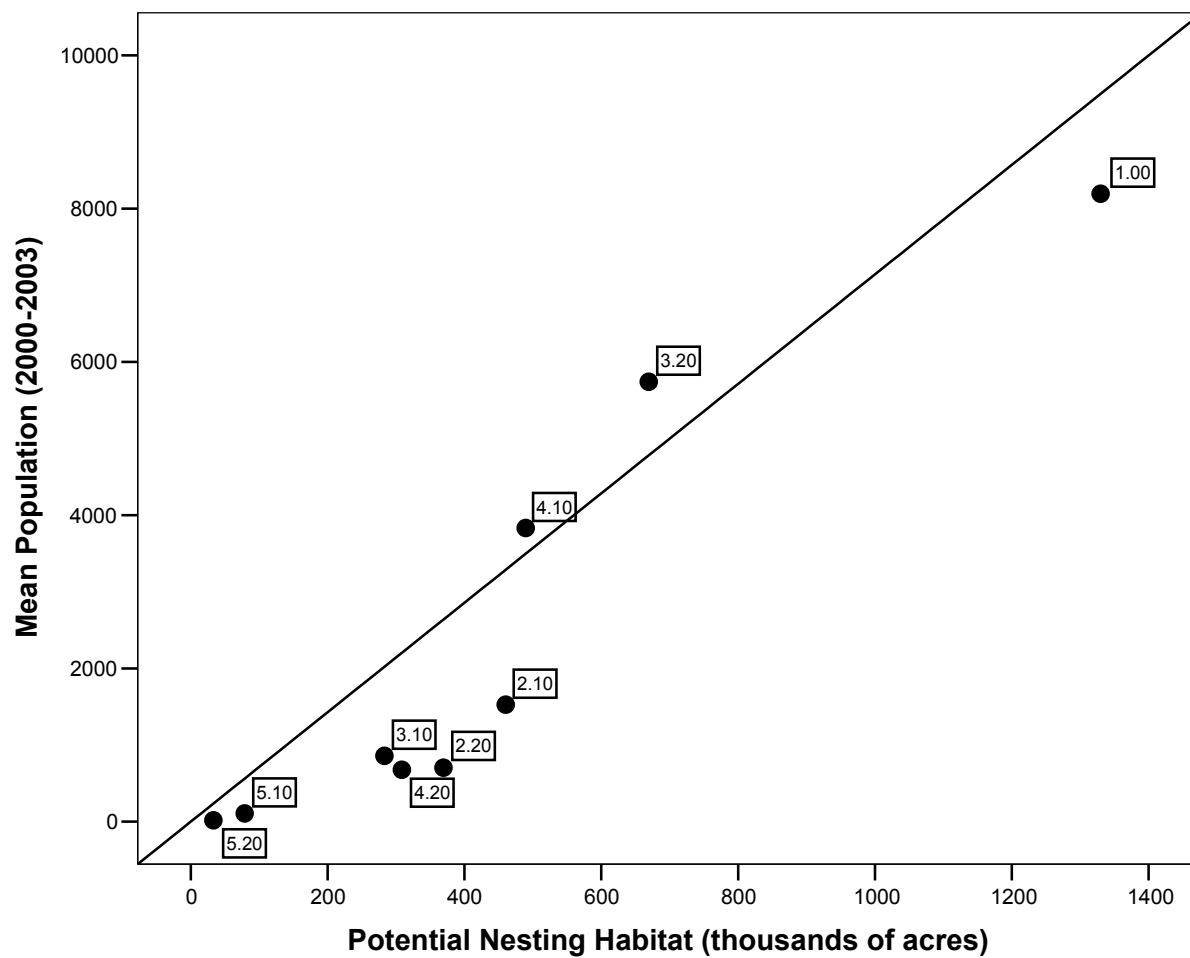


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Footnotes**Chapter 8: Conservation of Other Species Associated with Older Forest****Conditions**

Bruce G. Marcot and Randy Molina

Introduction

This chapter presents information on expectations and outcomes for species closely associated with older (late-successional and old-growth) forests (hereafter referred to as “LSOG species”), other than fish (see chapter 9) and northern spotted owls and marbled murrelets (see chapter 7), that were considered as part of the Northwest Forest Plan (the Plan). Many of the LSOG species are rare and little known, and include fungi, lichens, bryophytes (mosses and liverworts), vascular plants, invertebrates (mostly mollusks, and selected species groups of arthropods), and a few vertebrates. We also review the Survey and Manage (SM) species program established under the Plan to provide for rare and poorly-known LSOG species.

In this chapter we discuss species outcomes and program outcomes pertaining to what was expected under the Plan, what occurred and if there were differences between expectations and observations, the extent to which differences were caused by the Plan, and if the Plan assumptions are still valid. We summarize lessons to learn both in terms of conservation concepts and program activities over the last decade.

Biodiversity was the Umbrella; Species Became the Focus

The Plan was instituted as an ecosystem management plan to attend, in part, to biological diversity. To this end, the Plan was expected to provide for functional LSOG forest ecosystems, including all associated species and all components of biodiversity. Biodiversity is generally defined (e.g., DeLong 1996, Raven 1994) as the variety of life and its processes, and includes structure, composition, and function of multiple levels of biological organization ranging from genes through population, species, functional groups, communities, and ecosystems (Noss 1990). Under the Plan, however, the focus on biodiversity narrowed to addressing mainly the composition, amount, dispersion, and dynamics of old forest vegetation communities (see chapter 6) and the presence and persistence of specific species, namely salmonids, spotted owls, marbled murrelets, and a set of other LSOG-associated species.

In this chapter we mostly trace the recent history of species-level conservation and associated programs of work under the Plan. In the next sections we review the recent history of LSOG species assessments and the Plan provisions for conservation of LSOG species. However, at the end of the chapter we will return to the broader vision of biodiversity conservation, where we review recent trends in conservation biology and how they may pertain to lessons learned under the past decade of the Plan.

A Brief History of LSOG Species Assessments under FEMAT and the Northwest Forest Plan

To help set the stage for much of the rest of this chapter, following is a brief summary of the rather complicated history of the assessments and administrative programs under the Plan pertaining to management of LSOG-associated species (fig. 1).

The Forest Ecosystem Management Assessment Team (FEMAT 1993) initially evaluated a list of 1,120 LSOG-associated species under Option 9; this option, with some changes, became the basis for the Northwest Forest Plan under the 1994 Final Environmental Impact Statement (EIS; USDA and USDI 1994a). The 1994 EIS then identified 4 sets of criteria (“screens”) by which the 1,120 LSOG species were further evaluated to determine their appropriate conservation categories. The screens resulted in 791 of these species not being carried forward under mitigation for their conservation in addition to the NWFP provisions, whereas the remainder of the species was determined to entail additional conservation and evaluation under further mitigation.

A set of 23 mitigations was specified in the 1994 Record of Decision (ROD; USDA and USDI 1994b). One of the mitigations was the original Survey and Manage (SM) species mitigation which categorized each of 404³ individual species and 4 arthropod species groups⁴ according to 4 conservation classes, each class having a set of mitigation standards and guidelines. Standards and guidelines consisted of employing a variety of survey approaches (preproject or predisturbance, extensive, and general regional surveys) along with guidelines to protect (manage) known sites and to select high priority sites for management. New information gained from surveys would address the uncertainty regarding species persistence concerns and would inform decisions.

In 2001, a new EIS and ROD were issued (USDA and USDI 2001) to revise the SM species program procedures to specify greater details on conducting annual species reviews (ASRs),

species management requirements, the use of strategic surveys, and an expanded classification of 6 species conservation categories. Subsequent ASRs held 2001-2003 used the new (2001) survey guidelines and evaluation procedures, and resulted in 108 SM species being dropped from the SM species program as a result of the new data and evaluations. This left 296 individual species and 4 arthropod species groups remaining in the SM program. The SM program was eventually removed after issuance of a supplemental EIS in 2003 and its associated ROD in 2004 (USDA and USDI 2004a, 2004b⁵), which moved 152 of the remaining 296 SM species to the Forest Services' Sensitive Species Program and the Bureau of Land Management's Special Status Species Program.

A Summary of Northwest Forest Plan Provisions for LSOG Species

The Plan, as guided by the 2001 ROD, contained several provisions for conservation of LSOG species. These included the delineation of late-successional reserves (LSRs) designed to accommodate populations of northern spotted owls, marbled murrelets, LSOG species, and other objectives; the delineation and protection of known sites of Survey and Manage Species found outside the LSRs in "mini" reserves (dubbed LSR3s in the Plan); delineation and protection of high-priority sites of selected SM species; and the expectation that some LSOG species locations and habitats would be provided by other measures to protect older forest components such as from the Aquatic Conservation Strategy and riparian reserves. In general, the major land allocations under the Plan were expected to provide habitat in appropriate amounts and distribution to support most LSOG-associated species.

What Was Expected Under The Northwest Forest Plan?

Expectations of Species Outcomes

Persistence of LSOG species and biodiversity—

Under the Plan, the management guidelines and land allocations, particularly the late-successional reserves, were expected to provide for persistence of most native LSOG-associated species (and all other elements of LSOG biodiversity). This specifically included the 791 species not requiring mitigations of the Survey and Manage Species (SM) Program but that were expected to be provided for by the late successional reserves and other mitigations specified in the 1994 Record of Decision (USDA and USDI 1994b), and the 404 individual rare and little-known species and 4 arthropod species groups that would require additional consideration and protection under the SM Program. The Plan did not specifically define either “rare” or “little-known” in identifying these lists of species. As necessary, species- or taxon-specific assessments would be conducted to help determine where and what additional management guidelines would pertain to ensuring persistence of species and biodiversity elements not otherwise provided.

Reduction of uncertainty and avoidance of listing—

For the 404 individual species and 4 arthropod species groups, it was generally expected that knowledge gained from SM program surveys, together with immediate protection of known sites, would help reduce scientific uncertainty, reduce risk to their extirpation, and increase overall chances for their persistence within the plan area. Such mitigation activities under the

SM Program would be expected to stave off potential Federal listing of LSOG-associated species.

Expectations of Program Outcomes

Adaptive management framework—

Expectations under the 1994 ROD (USDA and USDI 1994b) included that the SM program would provide an adaptive management framework for collecting new information on the 404 species and 4 arthropod species groups, for the purpose of evaluating and revising their conservation management status as deemed appropriate to ensure their persistence; and that the SM program would be a practical and economically efficient means to this end, with adequate resources to accomplish its objectives. It was also expected that sites would be protected for those species of high persistence concern, and that management recommendations would be developed to guide site management, which would entail protection on the order of tens of acres (with some exceptions) and some management treatments (e.g., prescribed fire for some vascular plants). The agencies would develop an interagency GIS database to house the information for analysis.

Survey protocols and species surveys—

It was further expected that effective survey protocols would be developed. The 1994 ROD (USDA and USDI 1994b) required surveys for amphibians and red tree vole to begin by 1997 and by 1999 for all other “strategy 2” species (species for which pre-disturbance surveys were to be conducted), and that protocols would be prioritized based on species risk level.

Pre-disturbance surveys would be conducted to avoid loss of sites for some species. Such surveys would start at the watershed analysis level to identify likely species based on habitat. For species for which pre-disturbance surveys were not required, likely sites would be identified at the individual project scale based on likely range and habitats. Multispecies surveys would be used as possible, and survey protocols and site management would be incorporated into interagency conservation strategies as part of ongoing planning efforts. This would include identifying “high priority sites” for protection. Broad scale (general regional) surveys would be implemented by 1996 and completed within 10 years, and major areas of scientific uncertainty on most species resolved during that period. The 2001 ROD noted that statistically-based “strategic surveys” (Molina and others 2003), together with other approaches including research and habitat modeling, would replace the previous extensive and general regional surveys, to provide more reliable scientific data on species rarity and habitat associations.

Changes in activities and no adverse affect on PSQ—

It was also expected that changes of management activities under the SM Program would include evaluating and potentially altering schedules for conducting surveys, moving species from one category to another, and dropping the SM mitigation for any species whose status is determined to be more secure than originally projected. The SM program would be expected to not adversely affect PSQ (potential timber sale quantity) beyond levels noted in the SEIS (USDA and USDI 1994a).

Annual species reviews—

As summarized above (also see fig. 1), the 2001 SEIS and ROD (USDA and USDI 2001) instituted a revised SM Program which was expected to provide clarity to ASRs as an adaptive evaluation process. It was expected that the data-gathering and ASR procedures would likely result in removing some species from the SM species list, and that NEPA documentation would not be made for decisions made under the ASR process. The ASRs would apply criteria for species' persistence, rarity, and association with LSOG forests and reserves to judge the category of SM mitigation for each species. The 2001 SEIS and ROD also provided criteria for potentially adding species to the SM list.

Biodiversity and rare species monitoring—

The 1994 ROD (USDA and USDI 1994b, pp. E-6, E-8 – E-11) explicitly called for effectiveness and validation monitoring of biodiversity and rare species. The 1994 ROD defined effectiveness monitoring as “evaluating if application of the management plan achieved the desired goals, and if the objectives of these standards and guidelines were met.” It specified that “Success may be measured against the standard of desired future condition... Effectiveness monitoring will be undertaken at a variety of reference sites in geographically and ecologically similar areas. These sites will be located on a number of different scales...” (USDA and USDI 1994b, p. E-6).

The 1994 ROD specified effectiveness monitoring of biological diversity and late-successional and old-growth forest ecosystems including “forest processes as well as forest species.” One evaluation question was stated in the 1994 ROD as: “Are habitat conditions for late-successional forest associated species maintained where adequate, and restored where inadequate?” The 1994 ROD stated that indicators for “assessing the condition and trends” include “seral development

and shifts of forest plant communities,” and that “key monitoring items” included “abundance and diversity of species associated with late-successional forest communities” and “species presence (to calculate species richness i.e., numbers and diversity)” (pp. E-8 – E-9).

The 1994 ROD also called for validation monitoring, which it defined as determining “if a cause and effect relationship exists between management activities and the indicators or resource being managed.” The 1994 ROD stated that validation monitoring asks “are the underlying management assumptions correct? Do the maintained or restored habitat conditions support stable and well-distributed populations of late-successional associated species?” The 1994 ROD also noted that key items to monitor include “rare and declining species” of plants or animals, including those federally or state listed, proposed, or candidate threatened or endangered, or listed by FS or BLM as sensitive or special status, or “infrequently encountered species not considered by any agency or group as endangered or threatened and classified in the FEMAT Report as rare.” This validation monitoring would focus on “the type, number, size and condition of special habitats over time” to “provide a good indication of the potential health of the special habitat-dependent species” (pp. E10 – E11).

The 1994 ROD acknowledged that habitat requirements of species can vary with age, size, or life cycle of the species, and with season, and also that although stable habitats are “not proof that a special habitat-dependent species population is stable, a decrease in a special habitat type does indicate increased risk to that species population.” The 1994 ROD also stated that “a monitoring program for rare and declining species will help to identify perceived present and future threats, increase future possibilities of discovering new locations, track their status and trends over time,

and ensure that, in times of limited agency resources, priority attention will be given to species most at risk” (p. E-11).

The 2001 ROD (USDA and USDI 2001) stated that monitoring, including Biological Diversity Effectiveness Monitoring, should continue as specified in the original 1994 ROD. The 2001 ROD also specified that the strategic surveys and the ASRs would contribute toward the validation monitoring phase.

What Has Occurred And Were There Differences Between Expectations And Observations?

Species Outcomes

Focus on LSOG species—

The Plan was implemented as a set of guidelines for land management allocations, along with additional mitigation guidelines for the evaluation and disposition of LSOG species under the SM program. Implementation of the Plan for LSOG species focused on species and their habitat relationships, and not on other biodiversity parameters such as other levels of biological organization, ecosystem processes, and organisms’ ecological functions. There has been no evaluation (including monitoring) of the degree to which the Plan has provided for these other aspects of biodiversity.

Evaluation of species rarity and persistence—

Under the ASRs, new data were collected on selected SM species and the species were reevaluated in an adaptive management framework to confirm or alter their conservation categories under the Plan. Although the term “rare” was never specifically defined by FEMAT or in the Plan, general criteria for determining species rarity were presented in the 2001 EIS and ROD (USDA and USDI 2001) that revised the SM Program with new conservation categories. These criteria included consideration for total number of locations, habitat and population trend, habitat fragmentation and population isolation, ecological amplitude of the species, distribution limitations, dispersal capability, and other factors (table 1). None of the criteria, however, was quantified. Also, different and potentially conflicting sets of criteria were presented in the 2001 EIS and Record of Decision for “rare” versus “uncommon” status of the SM species. Also, no specific criteria or procedures were presented for determining overall viability of the SM species (see later discussion on viability issues).

Results of forest vegetation monitoring (Spies, this volume) suggest a net increase in the total area of what is classified as late successional and old-growth forest vegetation cover over the decade of 1994-2004. However, it is not known the degree to which this “in-growth” of the old forest vegetation age class provides specific sites or microhabitat conditions used and selected by the individual species addressed in this chapter, nor if forests lost to fire and other causes over this same time period eliminated any such sites and microhabitats.

Surveys of rare species conducted—

The original assumption that many of the LSOG-associated species are rare has been partially borne out by surveys conducted over the past decade under the Plan. Data collected over the last

decade on number of locations of 399 SM species suggest that many of the species are known only from very few sites. About 42 percent of all species have been found from 10 or fewer sites (accounting for 6 percent of total sites in the database) (table 2). On the other end of the abundance spectrum, about 5 percent of the species account for most (2/3) of the sites and likely are not rare; these patterns held among all taxonomic groups (figs. 2, 3).

The four arthropod functional groups were included in the Plan because of concern that catastrophic disturbance, particularly wildfire, in southern Oregon and northern California could jeopardize their persistence. Given the impractical nature of surveying for potentially tens of thousands of arthropods in the four functional groups (at least some of which are likely to be unnamed species), the arthropod team instead chose a research strategy with three components: (1) examine the effects of experimental thinning and burning on select functional groups in a long-term ecological research site in northern California and identify indicator species, (2) conduct retrospective studies of resilience and recovery of the functional groups in areas with differing fire history in southern Oregon, and (3) conduct extensive literature reviews of insects in the region to identify potential threats to persistence. These were multiyear studies funded at about \$200-300K per year for 3-4 years, resulting in a set of publications and reports answering the basic 3 research components (e.g., Niwa and Peck 2002).

Assumptions of persistence of some species—

The general assumption under the Plan that the 791 LSOG species not originally included in the SM mitigation are indeed viable and persistent (and thus not requiring SM mitigation) remains formally untested, although these species might have benefited from increases in LSOG and the

reduced harvests over the past decade. No specific monitoring was established on these species under the Plan. Ancillary information may be available on some of these species under other research studies or agency programs (e.g., the Demonstration of Ecosystem Management Options [DEMO] project, research studies of riparian-associated species, effects of retention, and effects of silviculture on suites of species), but this has not been compiled and analyzed.

Identification and protection of LSOG species habitats and locations—

The expectation that the Plan would protect suitable locations or environments for many of the LSOG-associated species is partially borne out by results of the surveys that suggest that many species locations occur within Plan reserves (fig. 4). Many of the locations of fungi, lichens, bryophytes, and mollusks occurred outside Plan reserves. SM species could occur within the Plan reserves, and within LSOG in those reserves, in part by chance. Some SM species likely occur in reserves and matrix sites in non-LSOG vegetation stands having some LSOG components, such as large standing or down wood legacies.

Regardless, the degree to which locations within the Plan reserves would suffice to provide for long-term viability of the other 791 LSOG species was not determined. Additionally, no monitoring per se was instituted for either the original set of 404 SM species and 4 arthropod species groups or for other aspects of LSOG biodiversity. Only various surveys have been conducted, mostly for predisturbance evaluation.

A total of 67,891 locations are known within the area of the Plan on all originally-listed 404 SM species of all taxonomic groups, among all types of surveys (predisturbance, random grid, and

other). Of this total, 26,676 locations (39 percent) are in reserves. Among taxonomic groups, the proportion of all locations from reserves ranges from 35 percent (10,125 of 28,730 locations) for mollusks to 49 percent (7,742 of 15,942 locations) for lichens. These results are likely biased toward locations outside reserves (viz., in matrix lands) where predisturbance surveys were conducted. Of the total surveys conducted, 79 percent are pre-disturbance surveys. Protecting SM species sites in matrix lands had a far greater perceived impact on PSQ than expected. This was primarily due to the 5 percent of the species noted previously that turned out not to be rare and were found with predisturbance surveys at nearly 40,000 sites, mostly in matrix lands (see lessons learned for further discussion on implications of the predisturbance survey approach).

Turley (2004) estimated that 67 percent of the federal land base of the Plan area consists of reserves which include administratively and Congressionally withdrawn areas, late-successional reserves, and managed late-successional reserves. The remaining 33 percent consists of matrix lands which here include timber management matrix lands, adaptive management areas, and riparian reserves designated under the Aquatic Conservation Strategy of the Northwest Forest Plan. Not all LSOG forest occurs in reserves, and not all reserve lands are LSOG forest; USDA and USDI (1994 [a or b](#)) estimated that 86 percent of existing late-successional forests are in reserves, so that 14 percent are in matrix lands.⁶

Program Outcomes

Adaptive management approach and annual species reviews—

In general, the SM Program did provide a useful adaptive learning framework by which new inventory and scientific information on the SM species was collected and analyzed, such as on number of locations from predisturbance surveys (figs. 5a, b) and other survey and information gathering efforts. The new information was used in the ASR procedures to reevaluate the conservation management status of each SM species, leading to the removal of some hundred species (about 25 percent) from the SM list during the overall SM Program (fig. 6). This was a significant achievement, based on an unprecedented, massive database on species locations.

The ASRs also served to reassign some species to different conservation categories as a function of new scientific information mostly on their distribution and habitat associations. For example, the 2003 ASR evaluations resulted in removing from the SM program 29 (16 percent) of the 181 species evaluated that year, based on new scientific information. The 2003 ASR also reassigned 65 (36 percent) of the species to a more conservative category, kept 75 (41 percent) of the species to the same conservation category, and moved 41 (23 percent) of the species to a less conservative category, with no voting bias detected among the ASR panelists (Marcot 2003, Marcot and Turley 2003). These changes—again, part of the adaptive management approach—were scientifically supported by findings from the vast inventories conducted through the SM program.

Effective survey protocols and species surveys—

Many expectations for the SM Program were met, particularly for developing and instituting effective species survey protocols, conducting predisturbance and strategic (including random-grid) surveys (Molina and others 2003), accreting new data on species locations, developing

databases and GIS information bases (with about 68,000 records), synthesizing science information for individual species into management recommendations and applying those recommendations to project plans, and identifying sites for which protection outside LSRs would be provided. Multispecies, probabilistic regionwide surveys called for in the 2001 SEIS were developed and implemented that provided opportunities to examine regional species distributions in reserves and their rarity.

Development of species evaluation tools—

Also, useful tools, such as decision models based on the 2001 ROD evaluation criteria, were developed and successfully used to aid decision-making during the ASR process (Marcot and others, submitted). Other models (viz., potential natural vegetation GIS models, e.g., Leshner 2005; and Bayesian belief network models, Marcot, submitted) for evaluating likelihood of habitat suitability for specific SM species had been developed but were only partially integrated into the program.

Some shortcomings in surveys—

Some expectations for the SM Program were not met, however, including the following. The SM program, particularly the predisturbance surveys and ASR procedures, proved to be far more expensive and administratively complex than initially expected. Except for a few species, “high priority sites” were not identified for protection, as called for in both the 1994 and 2001 RODs. Data on absence (lack of presence) of species from field surveys, particularly from predisturbance surveys, were not recorded, which was a major loss of otherwise useful information to build and test prediction models of species-habitat associations. Little habitat or

species abundance data were collected in predisturbance surveys, similarly impeding the ability to construct habitat models or incorporate population attributes into conservation plans.

What was the Extent to Which Differences Were Caused by the Northwest Forest Plan?

Species Outcomes

Conservation of LSOG species—

Many or most of the 1,120 LSOG-associated species originally identified by FEMAT are likely far better conserved due to the Plan, simply by dint of conservation of LSOG forests and forest elements in late-successional reserves, riparian reserves, and matrix management guidelines providing for protection of known locations of some LSOG species. There has been collected a considerable amount of information on the number of sites that were protected for each species. Although that information does not translate to population outcomes, it is nevertheless a significant finding. However, the specific population outcomes, especially of the rarest of SM species, are largely still unknown.

Little information on species persistence—

Much of the implementation of the Plan for other species has focused on procedures for identifying and, where appropriate, protecting locations of rare and little-known, LSOG-associated species, and gathering new information on their associations with land allocations and habitat conditions. Little work has been done on species trend monitoring, and on validation

monitoring of the expectations that the Plan has provided for their long-term persistence and viability.

Thus, it is difficult to conclude whether the Plan has indeed provided for the long-term persistence and viability of these species, although (1) protection was afforded to specific matrix land locations when identified through predisturbance surveys and (2) much of the managed landscape occurs as reserves in which a significant amount of LSOG forest remains and LSOG species locations occur. The assumption that the Plan has provided for viability—or conversely, that it has not adequately provided for some species -- is still a hypothesis to be tested, at least by monitoring trends in species' locations over time, although we have some incremental, useful insights on locations and number of occurrences of some species from the various surveys.

Much of the uncertainty remains on whether the Plan has indeed provided for the long-term persistence and viability of a number of the LSOG-associated species and their ecosystem functions, particularly for the more rare of the SM species. A number of the less rare SM species, however, were removed from the SM species list by the annual species reviews and these species were deemed to be secure under the Plan.

Some major reductions in uncertainty—

Although much remains to be learned about life histories and ecological functions of most LOSG species, knowledge gained on specific distribution and abundance of many of these species has helped greatly reduce scientific uncertainty. In turn, as used in the ASR process, this information

helped reduce management uncertainty and increased reliability of management decisions on the conservation requirements of these species. This has not been a trivial accomplishment.

Still, some scientific and management uncertainty remains, including on SM species that were “downgraded” in conservation status under the SM Species Program, because only indirect, surrogate measures were used to judge the species’ persistence. For some species, better data were gathered by use of random grid (strategic) surveys, species-habitat modeling, and other efforts. For these species, some of the uncertainty in their projected persistence was greatly reduced.

Program Outcomes

Perceived impact on timber PSQ—

The predisturbance surveys and their results impacted matrix land management and were viewed as being largely responsible for a far greater impact on PSQ than initially expected (see lessons learned for more details).

Organizational complexity—

Working across agencies to evaluate the entire federal land base (BLM + NFS) created a layer of organizational complexity that (adversely) affected timeliness in getting work done, and also in running a regional program that had a large component independently implemented by field staff. We discuss organizational issues further under lessons learned.

Avoiding federal species listings—

The expectation that the Plan would help stave off Federal listing of LSOG-associated species has been largely borne out, although listing petitions have been advanced for a few species including lynx and fisher. It is unclear, however, whether the lack of listing petitions for other LSOG-associated species was directly a result of the Plan, although the plan likely contributed to this outcome.

Are the Northwest Forest Plan Assumptions Still Valid?**Species Outcomes****Most LSOG species protected—**

The initial projection that the main elements of the Plan would provide LSOG environments for most, but not necessarily all, species is still valid. Population persistence of the 404 SM species and 4 arthropod species groups—as well as the 791 species deemed to be effectively cared for under the Plan— is still untested.

Protection of some of the rarest species provided, other still uncertain—

The expectation that some species might garner additional conservation attention beyond the main elements of the Plan (ACS, riparian reserves, LSRs, matrix guidelines) was validated by the work of the annual species reviews. That is, based on the outcome of the ASRs, the late-successional and riparian reserves might **not** suffice to fully ensure protection and persistence of all LSOG species. Additional, species-specific assessments and considerations, as were

conducted under the SM program and ASRs, likely are part of meeting this goal. This is particularly true for the rarest species (i.e., those known from <20 sites) that had known locations outside of reserves. Thomas and others (1993) provide a detailed example of increased levels of protection granted to species with the addition of each new layer of a multi-layered plan such as the Plan. One of the successes of the SM program was identification of known sites for protection of the rarest species outside reserves.

Program Outcomes

Disposition of the SM program—

Final consideration of the validity of plan assumptions for the SM program is problematic because the SM standards and guidelines were removed from the Plan in 2004 (USDA and USDI 2004b). The SM program was controversial since its inception, resulting in litigations with different publics and eventual development of two SM SEIS analyses and RODs to deal with implementation issues. Some of those issues were noted above, particularly the adverse impact on PSQ of management decisions not to continue projects (e.g. timber harvest) in numerous matrix sites where SM species were detected through predisturbance surveys. The 2001 ROD (USDA and USDI 2001) also documented the adverse impact of SM mitigation activities on ability to conduct healthy forest and fire reduction projects in much of the Plan area.

In response to a 2001 lawsuit brought by the timber industry (Douglas Timber Operation, and others v. Secretary of Agriculture. Civil No. 01-6378 – AA), the administration settled and agreed to conduct a new SEIS on the SM program wherein one alternative would consider

movement of SM species to the agencies' special status and sensitive species programs (SSSSP). In the resulting 2004 SM SEIS (USDA and UDSI 2004a), the agencies described their many frustrations in implementing the SM program mitigation and overall adverse impact it had on meeting other important NWFP objectives (e.g. PSQ, healthy forest restoration, and other management projects) and the high cost of the program. They selected a preferred alternative that removed the SM standards and guidelines developed in the 1994 and 2001 ROD (USDA and USDI 1994b, 2001) and moved 152 of the remaining 296 species into the BLM and FS SSSSP; 57 species not added to the SSSSP were projected to have insufficient habitat for persistence under this preferred alternative compared to a projection of sufficient habitat under the 2001 SM ROD (USDA and USDI 2001). The 2004 SEIS and ROD clearly described the risks to species extirpation and management risk tolerance in making these decisions. The agencies emphasized the probable contributions of the Plan area in late successional reserves (80 percent of the plan area), the risks to rare species persistence inherent in dynamic landscapes, and the stated desire to balance the uncertain nature of conserving these rare and little known species with meeting other critical plan objectives (see USDA and USDI 2004b, pages 9-13, for more details). Cost benefits of the SM program were also given detailed analyses.

The 2003 SEIS and 2004 ROD provided detailed effects analyses on the risk to extirpation of SM species under the three alternatives based on available data and expert opinion. The overall objectives of the SSSSP differ from the SM program, and SSSSP coordinators and field managers face many of the same challenges that SM staff did in conserving these species; many of the SM taxa such as fungi have not previously been included in the SSSSP. Therefore, the SSSSP could take advantage of the known site data base, distribution maps, science documents,

management guidelines, survey protocols, and conservation strategies pioneered and developed by the SM program. In approving the 2004 ROD, the Regional Executives apparently clearly understood the challenges and impact of moving 152 SM species to the SSSSP in Oregon and Washington, and have supported this transfer of knowledge gained from SM. They also have increased resources (funding and permanent regional staff) to accomplish the increased workload for these and other tasks. A section that follows on information gained and lessons learned from the SM program further supports the potential value of transferring key findings. The 2004 ROD was challenged and the resulting litigation and resolution are still pending.

Information Gained and Lessons Learned

Information Gained on Rare and Little Known Species

One of the underlying challenges, and indeed an underpinning for the adaptive approach of SM, was lack of fundamental information on species presence, distribution, abundance, biology, ecology, and conservation status: How rare are they? How are they distributed throughout the plan area? How abundant are their populations? What are their primary habitat requirements? What factors are influencing their risk of extirpation? Answers to these questions are fundamental to discovering how well the Plan provides habitat for maintaining well-distributed, viable populations (i.e., meeting the original mission objective for LSOG-associated species) and how to best manage, protect, or restore habitat to meet that original objective. The collection of nearly 68,000 known site records for all SM species over 10 years of plan implementation provided the basis for unraveling some of this uncertainty for many species and allowed for informed science-based management decisions on their conservation.

Given new information on rarity, distribution in reserves, degree of LSOG-association, and persistence concerns, over 100 species were removed from the SM list because they no longer qualified for the SM mitigation. Many of these species were removed because they were not as rare as originally believed. The removal of these less rare species was an important adaptive decision because they accounted for many thousands of sites in the matrix; once removed from SM these sites were released to meet other forest harvest and management objectives.

Known site data also showed that most SM species were rare; 54 percent of the species were known from 20 or less sites, 42 percent from 10 or less sites, and 31 percent from 5 or less sites. The SM database includes sites from both federal and nonfederal forests. When nonfederal sites are removed from consideration, the percentage of actual sites protected under the Plan was smaller. Given the high percentage of species that showed such rarity, these data support the assumption made during FEMAT and the 1994 SEIS (USDA and USDI 1994a) that application of a fine filter strategy, in this case protection of known sites, would be an important strategy to maintain their viability. The discovery of many of these rare sightings outside of reserve land allocations further supported the protection of the few known sites to meet the objective of helping ensure conservation of these species.

Although the nearly 68,000 records allowed for better informed decisions, the data had shortfalls that limited their utility for answering the many questions noted previously. Lessons learned emerge from understanding the usefulness or limitations of the data. The vast majority of records are simply site locations with little or no information on habitat characteristics or species

abundance. Thus, even though distribution maps could be generated, they could not be used directly to analyze population trends and dynamics, nor to predict potential habitat or its distribution. Collecting information on species abundance or habitat characters, however, represents a significant expense compared to noting only presence.

It is important to carefully weigh what information helps to meet conservation objectives and the cost and benefit of obtaining that information in future inventory or monitoring surveys. If surrogate metrics are used to gauge species persistence and to reduce survey cost (e.g. using rarity alone without species abundance data), the science panel evaluations of the SM program's annual species reviews taught the importance of knowing the limitations of the data and integrating its uncertainty into management decisions (see later discussion on use of surrogates in species viability analyses).

There was also significant bias in the nearly 68,000 records because most were from predisturbance surveys conducted primarily in matrix land allocations. This bias would be considered when addressing questions of how well the plan, particularly the reserves, provided habitat for well distributed, viable populations. The course change documented in the 2001 SM ROD towards more reliance on strategic (including random-site) surveys than on predisturbance surveys was directed at resolving this issue.

Regardless of these shortcomings, on a regional scale, the nearly 68,000 record database is one of the largest and richest of its kind for poorly known taxa such as fungi, lichens, bryophytes, and mollusks. It could serve not only as a valuable resource for the SSSSP of Oregon and

Washington, but the rigorous procedures for inventory and amassing survey data could help in developing conservation strategies for rare and little-known taxa in other regions.

Information Gained and Lessons Learned from the SM Program

The SM program ploughed new ground in the science and conservation management of rare and little known species. Results of the SM program are pertinent not only to the stated objectives of the SSSSP, but also to conservation programs worldwide that are grappling with similar challenges in conservation of rare and little-known species. In identifying the challenges of managing biological diversity in Oregon and Washington as part of the PNW Station's Biodiversity Initiative (Molina 2004), Molina (unpublished data) found that numerous clients from inside and outside federal agencies voiced the desire to summarize and make available results from the SM program. We highlight here some of the major results and accomplishments of the SM program with a focus on lessons learned for potential use in future conservation efforts.

Management recommendations, survey protocols, and field guides—

Developing science-based management recommendations (MRs) was critical to meeting the assumption that agencies could provide immediate site management for species of high concern. The MR documents served two major functions. First, they summarized the best knowledge available on the biology, ecology, and natural history of the species. Second, they synthesized and integrated this knowledge into flexible guidelines so that managers could manage sites within their overall planning objectives. Recommendations focused on guidelines to maintain suitable habitat for species at the site scale.

Survey protocols identified when and where surveys were to be done, and the sampling procedures, the information to collect, and the survey skills required. Field guides for collection, identification, and processing of fungi and mollusks, two of the more difficult taxa, also were developed (e.g., Castellano and others 1999, 2003; Frest and Johannes 1999). All MRs, survey protocols, and field guides documents are available on line (www.or.blm.gov/surveyandmanage) and provide the most extensive management guidance to inventory and manage habitat for these taxa. These documents are available for the SSSSP efforts.

Development of an interagency species database—

As directed under the 1994 ROD, the SM program strove to develop an interagency database capable of mapping known locations through GIS procedures to aid analysis of other critical habitat and species attributes.

Development began as a simple “known site” database with much of the information coming from herbaria, museums, and agency data collected as part of the FEMAT and the Plan processes. In 1999, the new database (called the Interagency Species Management System or ISMS) came on line with full time staff. After extensive training of field staff on ISMS use, new data were entered and analyses conducted as part of the annual species review process. At the conclusion of the SM program nearly 70,000 survey records were housed in the ISMS database. This is the largest known assemblage of site and habitat data for these particular taxa.

The data, resulting maps, and analyses were used in the ASR process and, later, by the Natural Heritage Program to place species into the agencies' SSSSP when the SM program was terminated. The ISMS data base has now migrated to the new interagency Geographic Biotic Observations (GeoBOB) database and provides the framework for future GIS analysis and planning for the conservation of species in the SSSSP program and elsewhere.

Predisturbance surveys—

The intent of predisturbance surveys was to avoid the inadvertent loss of sites to maintain species persistence, particularly for rare species found outside reserves in matrix lands. As noted previously, predisturbance surveys became the most costly and controversial part of the SM program.

The 1994 ROD stated that most preproject surveys would begin with a watershed analysis and would identify likely habitat therein that required survey of the SM species. However, because so little was known about the habitat for these species, most surveys were conducted at the project level (i.e., nearly all managements projects required preproject surveys, often for multiple species). Surveys often were expensive and constrained by lack of trained personnel, and some species survey protocols were difficult and time consuming.

Field managers often stalled or cancelled projects because of the presence of SM species at the project sites. Eventually many of these species that turned out not to be as rare as previously known were removed from the SM program, but not until late in the program. The end result was a major impact on meeting the timber PSQ.

Although the conduct of predisturbance surveys met the expectation of avoiding inadvertent loss of sites, it became an unintended dominant aspect of the program. About 75 percent of all ISMS records were from preproject surveys, and these were only for about 10 percent of all SM species. When survey protocols were developed, data on habitat features and species abundance were not required, so these survey records mostly consisted of only a “known site” location. Nor were negative findings typically recorded from these surveys. The predisturbance survey data did not aid understanding of species’ habitat requirements and had limited utility for building habitat models of species’ habitat associations by which to predict occurrence on the landscape.

Three valuable lessons emerge from the predisturbance survey effort: (1) Predisturbance surveys can locate new sites and aid in rare species protection, but often provide biased data of limited value in understanding species distribution, habitat selection, persistence, and conservation management. (2) Presence/absence data is of limited value in understanding species viability and conservation management; data on habitat and species abundance are required to better inform decisions on management for species persistence. (3) An adaptive process to quickly review and evaluate the effectiveness and cost/benefit of survey strategies is important to meet long term goals. The 2001 ROD recognized some of these issues and emphasized that strategic surveys that would focus on reserve lands were required.

Strategic surveys—

Strategic surveys, which were to be conducted on both matrix and reserve lands as well as in LSOG and non-LSOG, were developed as an underpinning for the 2001 SM ROD for three

reasons. First, the agencies recognized that predisturbance surveys were not targeting reserve lands because most projects occurred in the matrix. A fundamental uncertainty of the SM mitigation was how well the reserves provide for species persistence. Second, little habitat or abundance data were collected in preproject surveys; this information is vital to understanding habitat association and designating high priority sites as part of conservation plan development. Third, the SM program was based on an organizing principle and vision tool to work through the priorities of the SM program to bring better balance to meeting species conservation with other Plan objectives such as timber harvest. The strategic survey effort together with the newly defined annual species review process was designed to address these issues.

The strategic survey effort followed the adaptive framework developed by Molina and others (2003). The framework represents an iterative process that identifies specific information gaps, prioritizes species based on biological or management gaps, designs and implements efficient survey approaches, and then analyzes the survey findings as part of the annual species review. A new set of information gaps is identified from these analyses and the planning and implementation process is repeated. The strength of this approach is that it is designed to address specific questions that reflect priority information gaps.

Strategic surveys included a wide variety of approaches to fill information gaps, including research and modeling approaches. This variety of approaches increased flexibility of the overall program and enhanced opportunities for partnerships between managers and researchers. Such a flexible “strategic” approach could enhance the effectiveness of the SSSSP, particularly in dealing with species such as fungi where predisturbance surveys largely remain impractical.

Landscape scale surveys, for example, that cross BLM and FS district boundaries and that use a statistically designed sampling scheme, could help field managers to share resources for collecting and analyzing data throughout a significant portion of a species' range. We provide results below from one example of this approach, the random grid survey.

Random grid surveys—

In 1999 regional leadership requested development of a broad scale survey throughout the Plan area that would provide valuable information on all SM species (i.e., use a multiple species approach) concerning their rarity and distribution in LSOG habitat and reserves. The survey would be statistically designed to allow for use of probabilistic inferences of species' occurrence across the plan area. Working in consultation with a team of statisticians, a strategic survey workgroup developed what is called the random grid survey (see Cutler and others 2002 and Molina and others 2003 for a discussion of the strengths and weaknesses of this survey approach).

The random-grid survey uses permanent points on the landscape (the FIA and CVS grid) that contain a wealth of information on stand age, composition, and structure (e.g., amount of coarse woody debris and number of snags). Seven hundred fifty randomly selected sampling points were stratified into LSOG vs. non-LSOG (LSOG = forests > 80 years) and reserve vs. matrix lands to address the primary questions of LSOG and reserve association of each species.

Occurrence estimates of each species were calculated by extrapolation of the number of sites at which the species was found to predict occurrences over the survey area. Implementing this survey for about 300 species was extremely complex and expensive (about \$8 million) and took

over 2 years to complete. Nearly 240 people were involved in planning, execution, specimen identification, analysis, and reporting. Final results are still in the reporting stage so we can only provide a limited summary at this time.

Overall, it appears that the random grid survey met some of the original expectations and objectives. Approximately 3,000 new records were added on 179 SM species, roughly one third on lichens and another third on fungi. Figure 7 shows, however, that most species were found from only 10 or fewer sites each, one third were found from one or two sites, and 40 percent of the species were not found at all. This is the general result predicted by Cutler and others (2002) who noted that this broad scale type of survey would likely not detect extremely rare species. Although that was true overall, a few very rare species (i.e., known from only a few sites) were detected in the survey.

Results from the random grid survey also helped expand the known overall distribution of several species. However, evaluating the degree of association of the SM species with LSOG or reserve lands proved difficult because these analyses require at least 10 detections for a reasonable amount of certainty. Of the 41 species with 10 or more detections, about 30 showed a statistical association with LSOG and 7 with reserve or matrix land allocations (two with reserves and five with matrix). Regardless of statistically significant results, knowing that species were detected in reserves may be useful because this information was previously lacking in the ISMS database.

Figure 7 also shows that several species were detected frequently on the random grid. Most of these species had already been removed from the SM list or were being viewed in the annual species reviews as not rare.

Although the random grid survey data analyses were not completed prior to the termination of the SM program, preliminary results were used in the annual species review. For example, some species were removed from the SM species list in part because the random grid surveys suggested the species were not rare within the NWFP area.

Given the mixed results (few to no locations of very rare species, but useful information on other species on LSOG and reserve association) and great expense of the random grid survey, the SSSSP may wish to carefully review the findings and identify advantages of this survey approach, to help meet program objectives (see Edwards and others 2004 for further discussion).

Annual species reviews—

One the more successful outcomes of the SM program was the annual species review (ASR), designed as an adaptive decision framework to address uncertainty and provide new information to guide SM species conservation decisions. The 2001 ROD revised and expanded the ASR process and provided specific criteria and guidelines by which panels of species experts and evaluators would summarize and interpret ecological attributes of each SM species for reevaluation of the species' conservation status under the Plan.

Using this process, the agencies removed about one quarter of all SM species from the list, and changed categories of several species to either a more or less conservatory status, to reflect mitigation. Decisions to remove some species provided the agencies with the latitude to permit other management activities to proceed on those sites.

The ASR process was not a formal population viability analysis (PVA) but rather a decision process that used a number of surrogate factors that represented species rarity and persistence. It is unlikely that traditional PVAs--which demand data on demography, population genetics, community interactions, and other ecological factors--could be conducted on most of the SM species owing to the species' rarity and to the dearth of quantitative information. Thus, it was vital to ensure that the ASRs served as a rigorous decision analysis procedure. To this end, the 2001 ROD guidelines specifying the criteria for the ASR species evaluations were formalized into a set of BBN decision models (Marcot and others, submitted). The models were used by the ASR evaluation panels to determine which categories of conservation status, if any, might pertain to each species given the scientific data. The models clearly showed how the surrogate factors were used to judge potential conservation status categories, and the ASR evaluation panel fully documented their use of the data and model outcomes in their recommendations. Thus, the overall ASR process was trackable, rigorously conducted, and fully documented. Many of the processes used in the ASR may prove valuable in assessing SSSSP species status and trends.

Selecting high priority sites for management—

The 2001 ROD also specified identifying “high priority sites” for some of the SM species categories (for uncommon species whose status was not undetermined). Selecting high priority

sites for management was intended to provide a measure of protection for the species but also allow some sites to be used for other management objectives such as forest stand thinning and timber harvest.

This aspect of the SM program was slow to be implemented and by the end of the SM program, plans were still in developmental stages for only a few species. This was an unfortunate outcome because these plans (i.e. selecting high priority sites for management) was a key process to release known sites in the matrix for other management objectives.

The plans under development used information from watershed analyses to determine where critical sites occurred in relation to nearby reserves with suitable habitat. These plans and the process used to develop them, may provide useful tools for the SSSSP, particularly in evaluating the degree to which reserve lands could provide for species and could thereby defer the development of site-specific protection measures.

Program organization and implementation—

Implementing the SM mitigation became a far more complex, expensive, and process-driven program than originally envisioned by the FEMAT and SEIS writers (Holthausen 2004).

Reasons for this are many and varied. Although some aspects of the SM program were expected to be expensive (tables 3-6), final costs exceeded expectations, particularly in conducting preproject surveys throughout the region by field units (see USDA and USDI 2001 and 2004 [a or b](#) for details on program costs). Available information makes it difficult to compare projected and actual costs.

The 1994 ROD provided little guidance for SM program organization and implementation. None of the original FEMAT or SEIS team members who developed the standards and guidelines of the Plan program participated in early development or design of the SM program, so original intentions may have been lost or overlooked. A group of interagency specialists eventually formed a “core team” to develop the SM program of work. Most of these specialists were assigned only part time to this project, with some members coming and going as details ended. A shortage of taxa expertise within the management agencies surfaced early in SM program implementation and impacted the ability of the SM program to develop science-based products (e.g. management recommendations and survey protocols) for over 400 poorly known, taxonomically diverse species. This shortage of expertise was especially critical on some taxa such as mollusks and fungi. Shortage of expertise also affected ability to develop products within deadlines envisioned by original planners. Nevertheless, the early SM organization struggled successfully to develop these essential products and to initiate broad regional surveys.

In 1999, as agencies began the SEIS process to redefine the SM mitigation (eventually resulting in the 2001 ROD), a new SM organization was established with permanent staff that was responsible for all aspects of program implementation. Permanent positions included a program manager, strategic survey coordinator, conservation planner, and annual species review coordinator. A team of four agency representatives continued to provide support for many tasks. Approximately 90 specialists from BLM and Forest Service field units (totaling 35 FTEs) worked on taxa teams to develop species-specific products and to conduct species evaluations. An interagency group of intermediate managers (the IMG) provided direct oversight and

leadership, thus enabling more efficient policy and management decisions. This new organization and leadership support greatly improved the efficiency and effectiveness of the program.

Much of the complexity and process-laden aspects of the SM program grew from the enormous task of building a science-based approach for conserving 400 poorly known species that required gathering new information over a 24-million-acre planning area. Working across BLM and FS agency boundaries, both organizationally and physically on the landscape, added another layer of complexity. Many SM tasks such as development of management recommendations and protocols, data base development and analysis, and species status evaluations, required regional oversight; other tasks such as conduct of preproject surveys and data collection were the responsibility of field units. Successfully implementing these tasks required new ways of communicating between agencies and between regional headquarters and district offices. In the end, the ability of agencies to cross these boundaries and overcome many of the challenges were perhaps some of the more successful aspects of the SM program, particularly after formation of the new SM permanent organization. Six federal agencies shared personnel and resources over several years to accomplish these many difficult tasks, thus meeting one of the primary goals of the Plan in working together to manage resources at a regional scale.

Several important lessons emerge regarding the organization of an effective science-based management conservation program. First, and most important, is having a long term vision that clearly articulates both short and long term objectives for the program. Such a vision was lacking in the early years of SM implementation so it was difficult to pull together the

complexity of tasks into a cohesive framework to measure success. Secondly, permanent expert staff assigned to the program provided continuity and accountability for meeting expectations far more efficiently than did staff temporarily assigned as detailers from other units. The SM program significantly enhanced its productivity and accountability with the development of a recognized program with permanent positions. The new positions added recently to the regional SSSSP is an important step in that direction. Third is development of effective communication between regional and field staff to provide timely information sharing of ongoing tasks, deadlines, and accomplishments. The SM website (www.or.blm.gov/surveyandmanage), annual reports, data calls, and field training workshops are good examples. Finally, connecting the program to a regional vision to conserve biodiversity would help to place the conservation of rare species in a broader agency mission context.

Considerations

Efficacy of Large Reserves for Conservation of Rare Species and Biodiversity

A central tenet of the Plan was that the system of late-successional reserves would largely suffice to provide for species and biodiversity components associated with late-successional and old-growth forest ecosystems. We have found that, to an extent, this is likely true. However, the degree to which late-successional reserves—along with the set of other Plan land allocations (e.g., riparian reserves in matrix lands)—suffice varies considerably by species and biodiversity component. It also likely varies by the specific locations chosen for the late-successional reserves—such as whether they happen to intersect unknown sites of particular species or

communities, and if they happen to contain microenvironmental conditions and specific habitat elements used and selected by those species or communities.

Initial findings (Turley 2004) of the random-grid survey study on SM species suggests that both Plan reserves and LSOG forests within and outside reserves may play key roles in providing habitat for many species. Out of a total 394 SM species targeted for survey in this study, sufficient data were gathered on 108 species (bryophytes, fungi, lichens, and mollusks) by which to determine degree of association with reserves and with LSOG. Of these 108 species, 41 species had 10 or more detections. These results alone suggest that most of the 394 SM species were seldom if ever encountered during the random grid survey, and thus results of this study pertain largely to the more abundant species. Of the 108 species tested for association with reserves, only 2 species (2 lichens) were significantly or marginally statistically associated with reserves, and 5 species (1 bryophyte, 1 fungus, 3 lichens) with matrix lands; the rest of the species showed no association with either reserve or matrix lands. Of the 108 species tested for association with LSOG, 30 species (3 bryophytes, 6 fungi, 20 lichens, 1 mollusk) were significantly or marginally statistically associated with LSOG, and 1 species (1 lichen) with non-LSOG lands; the rest of the species showed no association with either LSOG or non-LSOG.

These results suggest that about one third of all species that could be tested (again, being the more abundant of the SM species) were marginally to closely associated with LSOG, but only one SM species showed such association with reserves. This provides evidence that LSOG is important for at least 30 SM species—which is useful information not available before the study.

However, no information is available on the bulk (73 percent) of the more rare SM species (286 species) which were not found or which were undersampled for statistical analysis.

For all SM species combined, reserves per se were not specifically selected for; over all species detections from this study, 81 percent were found in reserves, compared to 80 percent of the land base sampled being in reserves. Still, the data on 10 species selecting for reserves was new and significant information. Also, lack of association with reserves should not necessarily be construed as reserves not providing important habitat for species persistence, particularly for those species that do show association with LSOG. LSOG occurs in both reserve and matrix lands, and over time if LSOG regrows within reserves and is reduced in matrix lands, such a study as this could detect greater association with reserves per se.

In general, to maintain a large component of late-successional forest species and biodiversity elements, a reserve system may be viewed as a major “coarse filter” component, although additional “fine filter” evaluations and guidelines for some species and biodiversity elements also may be included (see below).

Recent Trends in Conservation of Biodiversity

Alternative approaches to biodiversity conservation and their efficacy for rare species conservation—

In the past decade, much has been written on methods and approaches to biodiversity conservation. A main focus has been on species conservation, with emphasis on maintaining or

restoring viability of rare, declining, or listed species, although other dimensions of biodiversity besides individual species also have been addressed.

One example is the concept of coarse and fine filters in biodiversity conservation (Armstrong and others 2003, Reyers and others 2001). These terms have been used in a wide range of contexts but, in general, coarse filter refers to management of overall ecosystems and habitats and fine filter refers to management of specific habitats or sites for selected individual species. In a sense, the Plan follows this approach where the overall late-successional reserves, riparian reserves, and guidelines for old forest conservation and restoration constitute the coarse filter, and the SM program's focus on selected habitats and sites of rare species constituted the fine filter. The literature generally concurs that a combination of both coarse and fine filter elements better ensure conservation of a fuller array of species and biodiversity elements (Dobson and others 2001, Kintsch and Urban 2002). That is, applying just coarse filter management of general ecosystems and habitats alone would not suffice to ensure conservation of all biodiversity elements including rare species associated with uncommon microhabitats and environmental conditions (Lawler and others 2003).

Another approach to biodiversity conservation has been delineation of hot spots of high species richness or of locations of endemic or at-risk species, and use of "gap analysis" to determine where such hot spots fail to coincide with conservation-oriented land allocations (Flather and others 1997, Root and others 2003). Reliability of hot spot locations and gap analyses depend on the accuracy of underlying species distribution maps. Some studies suggest that the hot spot approach alone does not necessarily ensure protection of rare species and that focus on a diverse

suite of species representative of a range of variation within ecological communities may be a more effective approach (Chase and others 2000).

Other recent approaches to biodiversity conservation have been devised to use many forms of surrogate species, such as umbrella species, management and ecological indicator species, flagship species, species functional groups and ecosystem functioning (e.g., Hooper and others 2005), and others. Few of these approaches alone have proven fully reliable for ensuring conservation of rare species.

The conclusion is that, unless specifically targeted to address conservation requirements of rare species, alternative approaches to biodiversity conservation generally do not suffice to fully ensure persistence and protection of all rare species.

Monitoring of biodiversity—

The original ROD (USDA and USDI 1994b) called for effectiveness monitoring of biological diversity and late successional and old-growth forest ecosystems. Beyond the species-specific owl and murrelet population studies and the surveys conducted of SM species, little information has been gathered on the ecology of these species. Even at the species level, little information has been gathered on ecosystem functions of rare and little-known LSOG species, including SM species, especially in terms of their contribution to overall ecosystem processes. However, such information would be very difficult to gather. Any effort to monitor biodiversity would do well to consider the specific utility of such information in guiding forest management, and selection of surrogate measures for difficult parameters used for adaptive forest planning.

Considerations in Developing Species Conservation Programs

Although the Plan was considered a science-based plan, there remained significant uncertainties and untested assumptions after implementation. This was particularly true for the Survey and Manage program because this mitigation grew out of the uncertainty surrounding the viability of the species and how well the overall Plan (especially the reserve systems) provided for species persistence. Furthermore, most of the taxa listed for protection were rare or little known, so available science was meager on how best to conserve these species. These issues point to the benefits from partnering with research agencies and universities in developing the science basis for conservation programs. Indeed, some of the conservation issues may call for specific research approaches to develop new knowledge on specific areas of concern (e.g., from understanding individual species ecology to developing landscape sampling designs). From experience gained we offer the following considerations:

Research Partnerships

- Consider including research partners in initial program design.
- Consider clearly defining the role of research in adaptive management and decision processes.
- Consider identifying specific information gaps and developing appropriate research studies to fill those gaps.

Coarse vs. fine filter approaches

- Consider carefully defining what is meant by coarse and fine filter (i.e. what elements do these represent).
- Consider clearly laying out in your conservation program the contributions expected from these two approaches (e.g. role of reserves and protecting specific sites).

Species viability and persistence

- If these represent species management goals, consider clearly defining the terms and how you will measure obtaining that goal.

Value of metrics

- Consider clearly designing metrics to meet specific objectives
- Consider the limitations of surrogates (e.g. indicator or focal species) for meeting broad conservation objectives.
- Consider validating the use of surrogates in meeting conservation objectives.

Database

- Consider designing an effective data base for data storage and analysis that will meet both short and long-term objectives
- Consider developing a robust database that is easily query able by diverse users.
- Consider the types of analyses that are required from the data.
- Consider adequately staffing this function to provide for quality stewardship and timely analyses.

Survey Design

- Consider developing a framework and process to strategically focus resources on key information gaps.

- Consider exploring a variety of survey approaches and analyze these for efficiencies in terms of cost and information gained.
- Consider the value that certain types of surveys provide or do not provide (e.g. predisturbance surveys typically provide biased data on species distribution and abundance).
- Consider looking for efficiencies by designing surveys to include multiple species.
- Consider collecting information that is critical to meeting specific conservation objectives (e.g. habitat information for modeling, species abundances for population considerations).
- Consider using statistically designed surveys when possible that allow for extrapolation of results to larger landscapes.

Habitat modeling

- Consider exploring different habitat modeling approaches to meet specific conservation objectives.
- Consider the limitations of habitat modeling.

Decision support

- Consider developing decision support models that integrate relevant information.

Monitoring

- Consider developing a monitoring framework that will enable you to measure how well you meet specific objectives (e.g. species persistence, minimizing management effects, evaluating trends, etc.)

The Future

The Plan has been a remarkably ambitious effort designed, in part, to conserve a wide array of rare and little-known species across multiple taxonomic and ecological groups. Although the

charge for the conservation of most species now falls into another program (SSSSP), lessons learned from the Plan on species responses and program implementation can help guide successful outcomes.

The broader expectations for demonstrating conservation of forest biodiversity elements beyond rare species, and the direction in the Plan to address biodiversity issues through effectiveness monitoring (Ringold and others 1999), however, still remain as mostly unmet challenges.

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Table 1—Surrogate measures of population persistence and disposition under the Plan, as specified in the guidelines for the annual species review of non-fish LSOG-associated species other than northern spotted owls and marbled murrelets (USDA and USDI 2001). LSOG = late successional and old-growth forests

Parameter	Surrogates
Geographic range	<ul style="list-style-type: none"> - occurrence of species within or close to the Plan area - occurrence of suitable habitat within the Plan area
LSOG association	<ul style="list-style-type: none"> - abundance in LSOG - association with LSOG components - known association with LSOG forests - suspected by experts to be LSOG associated - BLM or USFS special status species - listed by states as species of concern - Federally listed by USFWS as threatened or endangered - USFWS candidate species - adequacy of field data to determine LSOG association
Population persistence provided by the Plan	<ul style="list-style-type: none"> - likely extant known sites occurring in part or all of its range - total number of individuals - number of individuals at most sites or in most population centers^a - estimated total number of sites^{a, b} - limitation of geographic range to the Plan area - distribution of habitat within the Plan area - distribution of individuals within the overall range of the species - proportion of sites and known habitats in reserves - proportion or amount of potential habitat within reserves - probability that habitat in reserves is occupied - whether all other guidelines of the Plan provide for population persistence
Data sufficiency	<ul style="list-style-type: none"> - sufficiency of information for evaluating basic criteria for including on SM species list - sufficiency of information for determining management for a reasonable assurance of persistence
Practicality of surveys	<ul style="list-style-type: none"> - predictability of the occurrence of the organism - visibility of the organism - limitation of expertise for identifying the organism - ease of identification of the organism - concerns for safety of surveyors

- risk to the species from collection for surveys
- surveyable in 2 field seasons
- survey methods can be developed within one year

Species rarity

To determine if the species is “rare:”

- limited distribution
- distribution within its range
- distribution within its habitat
- dispersal capability on Federal land
- reproductive characteristics that could limit population growth rate
- number of likely extant sites on Federal lands
- number of individuals per site^a
- population trend declining or not
- number of sites in reserves
- likelihood of sites or habitats in reserves
- ecological amplitude
- habitat trend declining or not
- habitat fragmentation lending to genetic isolation
- availability of microsite habitats
- factors beyond the Plan affecting rarity

To determine if the species is “uncommon:”

- number of extant sites
- number of individuals per site
- restriction of distribution within range or habitat
- ecological amplitude
- likelihood of sites in reserves
- population or habitat stability

^a Information derived from the random grid surveys (see text for explanation).

^b Not explicitly included as a guideline in the 2001 ROD but added as a criterion to the annual species review.

Table 2—Number of Survey and Manage Program species and their total locations within range categories of known locations

Number known locations	Number species	Percentage of total number species	Total locations
0	22	6	0
1	26	7	26
2-5	72	18	237
6-10	48	12	401
11-20	48	12	711
21-50	60	15	2,059
51-100	36	9	2,793
101-300	51	13	8,306
301-500	9	2	3,383
501-1,000	9	2	5,989
>1,000	18	5	44,347
Total	399	100	68,252

Table 3—Projected (anticipated) costs for survey activities over the life of the Survey and Manage program^a

Survey activity	Projected costs
	<i>Thousand dollars</i>
Bryophyte extensive and general regional surveys	100
Lichen extensive and general regional surveys	500
Vascular plants preproject surveys	330
Known locations for rare, endemic fungi (over 3 years)	1,000
Fungi extensive and general regional surveys (over 10 years)	10,000
Arthropods, 20 watershed Surveys	9,000
Total	20,930

^a Extensive and general regional surveys were expected to take at least 10 years.

Source: USDA and USDI 1994a, Appendix J2. Values do not include regional program implementation costs or pre-disturbance survey costs.

Table 4—Approximate regional expenditures of implementing the Survey and Manage program from 1994 to 1999

Cost Element	Costs
	<i>Thousand dollars</i>
Program management	600
Preparation of survey protocols, management recommendations, and field guides	1,905
Training and species identifications	1,566
Extensive and general regional surveys ^a	2,875
Known site database	610
Interagency Species Management System (ISMS)	1,100
Overhead	1,904
Subtotal regional program costs	10,560
Predisturbance surveys 1994-1998	1,000
Predisturbance surveys 1999	8,500
Total	20,060

^a Did not begin until 1996.

Source: USDA and USDI 2000: 410-412.

Table 5—Annual projected (anticipated) short-term (years 1-5) and long-term (years 6-10) costs, projected from 2001 onward, to implement the preferred alternative for the Survey and Manage program

Program level	Cost element	Short-term costs	Long-term costs
Thousand dollars			
Regional	Strategic surveys ^a	7,700	1,000
	Field guides, management recommendations, survey protocols	600	300
	Program management	500	500
	Data management	400	400
	Training, species identification	600	600
	Subtotal	9,800	2,800
Field	Pre-disturbance surveys for timber	8,200	6,100
	Pre-disturbance surveys for fire	10,300	7,700
	Pre-disturbance surveys for other	400	300
	Subtotal	18,900	13,400
Total		28,700	16,900

^a Beginning in 2001, strategic surveys replaced the extensive and general regional surveys.

Source: USDA and USDI 2000: 417-419.

Table 6—Approximate expenditures of the Survey and Manage program 2001–2004

Fiscal year	Regional program	Predisturbance surveys	Total
<i>Thousand dollars</i>			
2001	10,400 ^a	- ^b	-
2002	8,300 ^a	7,700 ^c	16,000
2003	6,100 ^a	-	-
2004	5,200 ^d	-	-
Total	30,000	>7,700	>16,000

^a Source: 2003 Survey and Manage annual report, p. 8:

http://www.or.blm.gov/surveyandmanage/AnnualStatusReport/2003/S_and_M-2003.pdf

^b Data unavailable in existing documentation.

^c Source: USDA and USDI 2004a: 215 noted that the level of expenditure for fiscal year 2002 fell short of predicted costs due to less pre-disturbance surveys that year and stated that the total spent for the program was \$16 million. The 2003 Annual Report shows program costs at \$8.3 million, so the pre-disturbance cost was calculated from the difference between total and regional costs.

^d Source: Survey and Manage regional program expenditure spreadsheet. On file with: Forest Service, Pacific Northwest Regional Office, Portland, Oregon.

Figure List

Figure 1—Lineage of administrative programs and National Environmental Policy Act environmental impact statement (EIS) and record of decision (ROD) documents under the Forest Ecosystem Management Assessment Team (FEMAT), the Plan (NWFP), and the Plan's Survey and Manage Species Program (SM), addressing species associated with late-successional and old-growth (LSOG) forests on Forest Service (FS) and Bureau of Land Management (BLM) administered lands.

Figure 2—Species abundance distribution of number of distinct locations of Survey and Manage Species (sites located through various surveys) within the Plan area, combined over all taxonomic groups. Note \log_{10} scale on x-axis. Note that most species are rare, for example, known from very few sites, but some species are apparently more abundant.

Figure 3—Species abundance distributions of number of distinct locations of Survey and Manage Species (sites located through various surveys) within the Plan area, by taxonomic group. Note \log_{10} scale on x-axis.

Figure 4—Number of known sites of species closely associated with late-successional and old-growth forests, located through various surveys, by reserve and non-reserve land allocations on BLM and FS lands within the Plan area. Reserves include adaptive management areas, administratively or congressionally withdrawn areas, and late-successional reserves (LSRs); non-reserve lands include riparian reserves (not separable in the database) and matrix lands.

Figure 5 A, B—Cumulative number of sites located from all surveys on all land allocations (reserves and matrix lands), by taxonomic group and year. Substantial progress was made in locating sites particularly between 1998 and 2000.

Figure 6—Number of species assumed closely associated with late-successional and old-growth forests as listed by the Forest Ecosystem Management Assessment Team (FEMAT) in 1994, in original guidelines of the 1994 EIS and Record of Decision (ROD) that instituted the Survey and Manage (SM) Species Program under the Northwest Forest Plan, in the revised guidelines of the 2001 EIS and ROD that revised the SM Species Program and its annual species review process, and at current time in 2004 at the termination of the SM Species Program. The decline in number of species was because of gathering of new information used in the adaptive management process of the annual species reviews.

Figure 7—Histogram of random grid survey data showing the distribution of number of species found at sampled grid points. Data represent a total of 2,985 occurrences found among 179 species of bryophytes, fungi, lichens and mollusks sampled on 660 grid points throughout the Plan area.

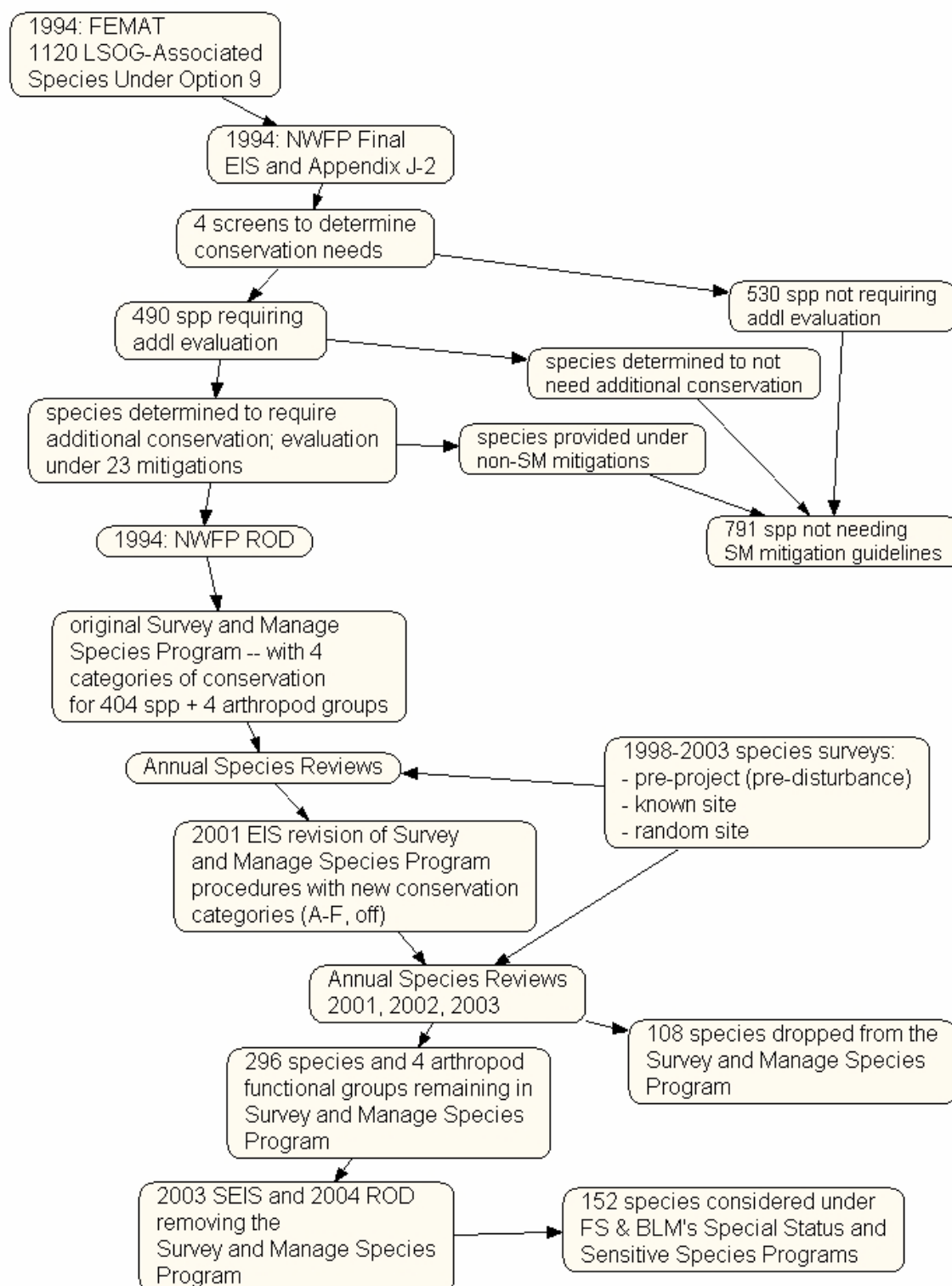


Figure 1

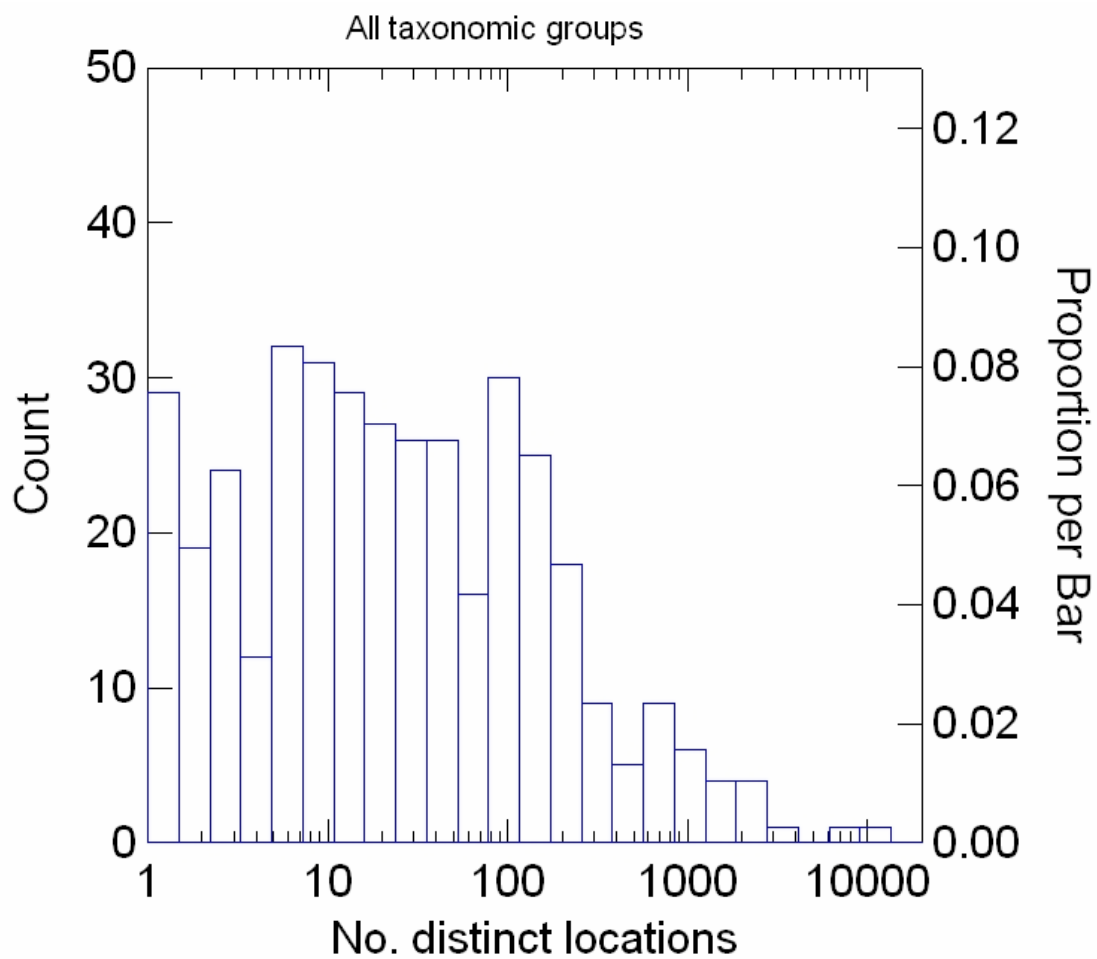


Figure 2

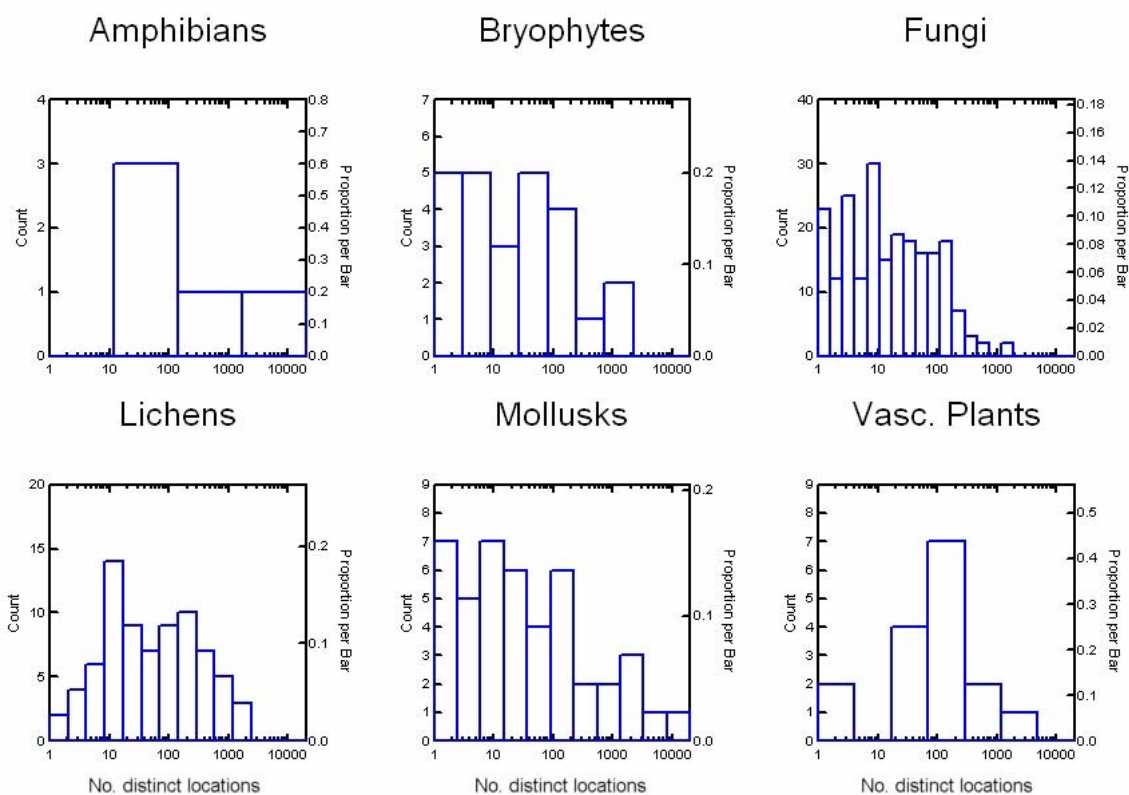


Figure 3

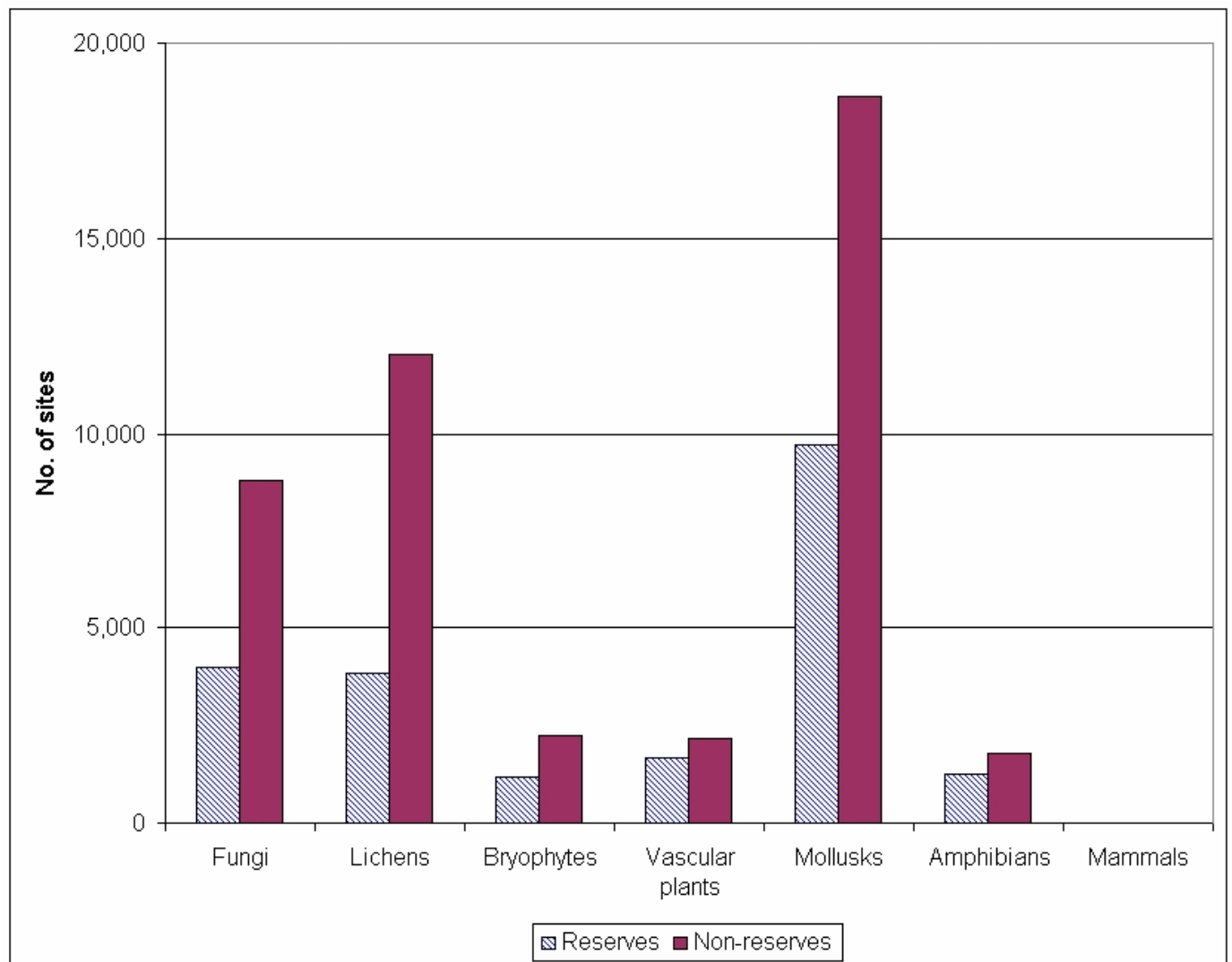
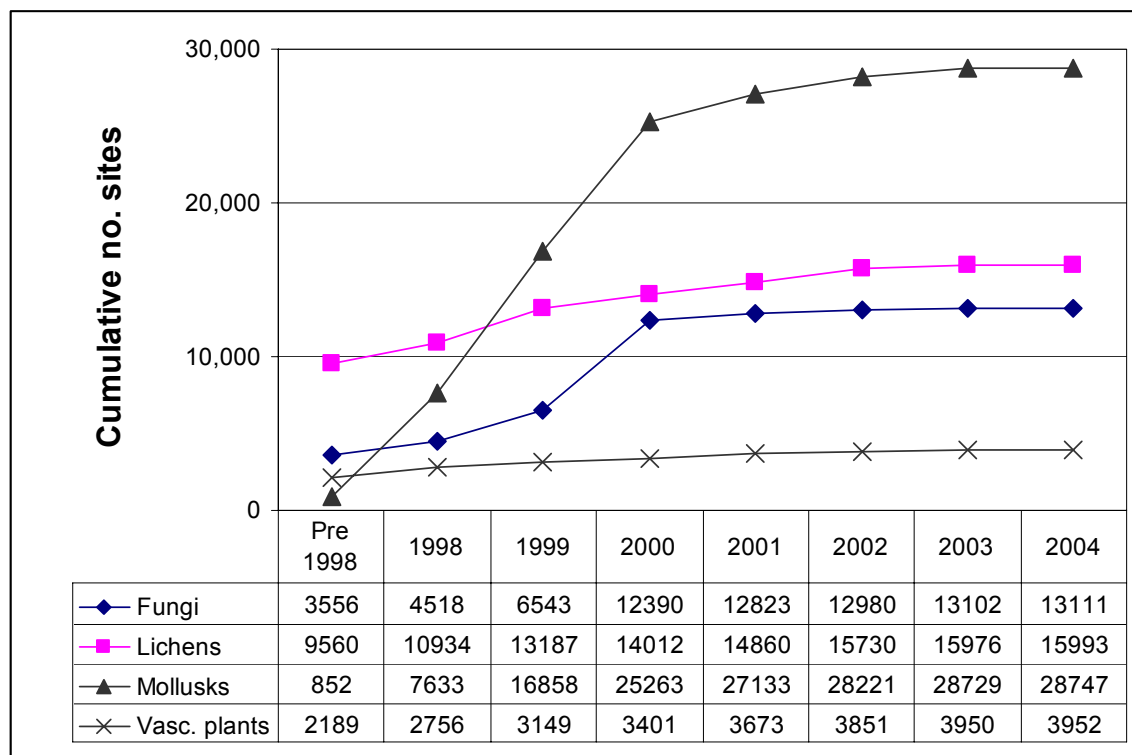
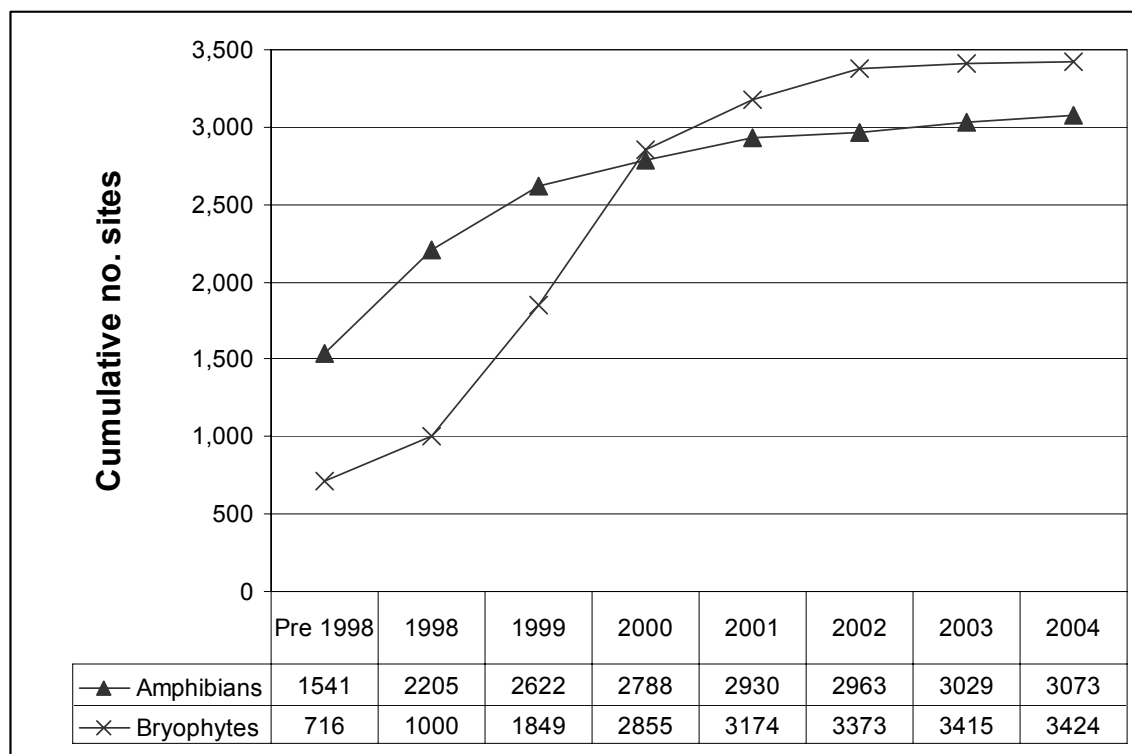


Figure 4

[Fig 5-A]



[Fig 5-B]



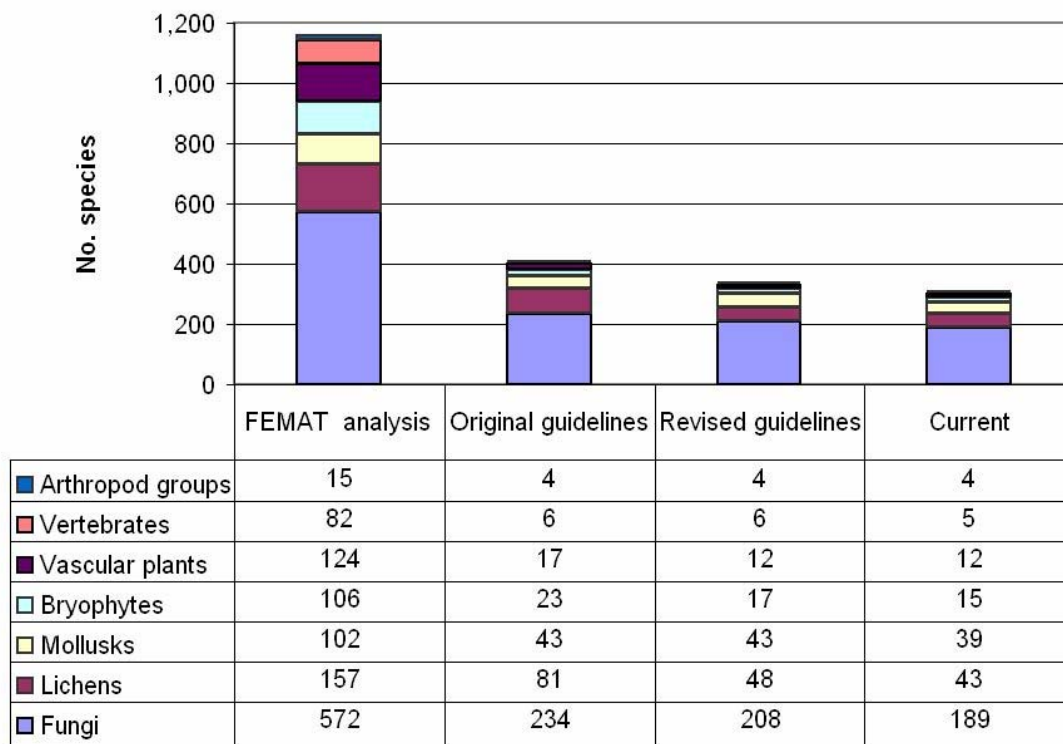


Figure 6

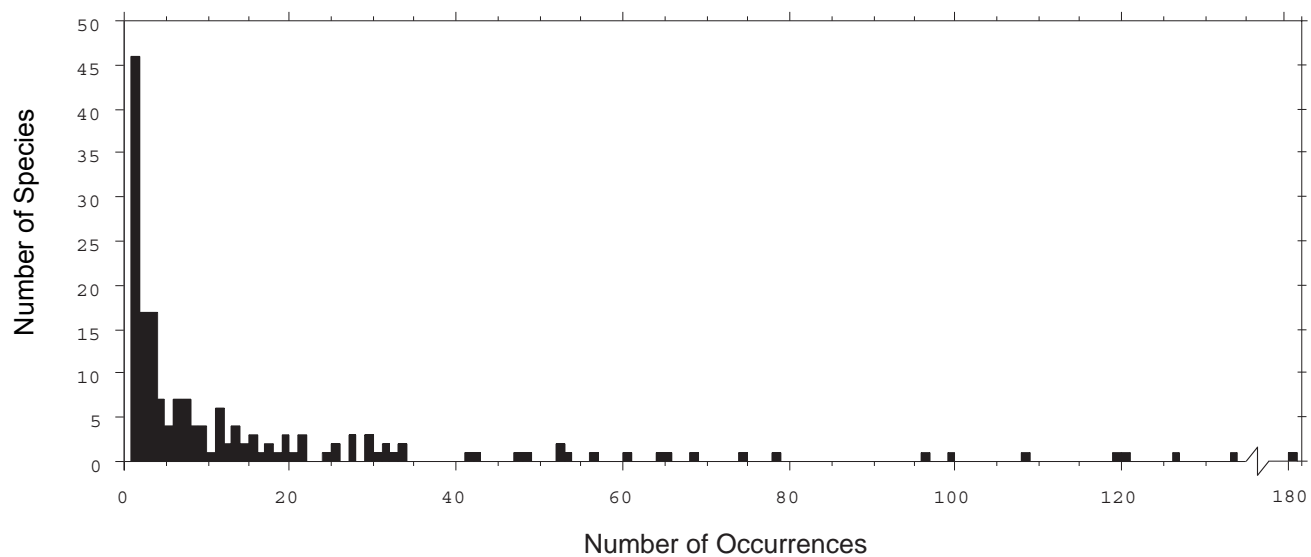


Figure 7

Footnotes

**Chapter 9: The Aquatic Conservation Strategy of the Northwest Forest Plan:
An Assessment after Ten Years**

Gordon H. Reeves

Introduction

The Aquatic Conservation Strategy (ACS) of the Northwest Forest Plan (the Plan) is a regional strategy designed to restore and maintain the processes that create and maintain conditions in aquatic ecosystems over time across the area inhabited by the northern spotted owl. It seeks to prevent further degradation of aquatic ecosystems and to restore habitat and the ecological processes responsible for creating of habitat over broad landscapes, as opposed to individual projects or small watersheds (USDA and USDI 1994b). The foundation of the ACS is a refinement of earlier strategies, “The Gang of Four” (Johnson and others 1991), PacFISH (USDA 1992), and the Scientific Assessment Team (Thomas and others 1993). Its primary objectives are to maintain and restore:

- the distribution, diversity, and complexity of watershed and landscape-scale features to ensure protection of the aquatic ecosystems to which species, populations, and communities are uniquely adapted;
- the spatial and temporal connectivity within and between watersheds;
- the physical integrity of aquatic ecosystems, including shorelines, banks, and bottom configurations;
- water quality necessary to support healthy riparian, aquatic, and wetland ecosystems;

- the sediment regime under which the aquatic ecosystem evolved;
- in-stream flows sufficient to create and sustain riparian, aquatic, and wetland habitats and to retain patterns of sediment, nutrient, and wood routing;
- the timing, variability, and duration of floodplain inundation and water table elevation in meadows and wetlands;
- the species composition and structural diversity of plant communities in riparian zones and wetlands;
- habitat to support well-distributed populations of native plant, vertebrate, and invertebrate riparian-dependent species.

In the short term (10-20 years), the ACS was designed to protect watersheds that currently had good habitat and fish populations (FEMAT 1993). The long-term goal (100 years) was to develop a network of functioning watersheds and that supported populations of fish and other aquatic and riparian-dependent organisms across the Plan area (USDA and USDI 1994b).

The ACS contains four components to meet these goals and objectives:

- **Watershed Analysis:** Watershed analysis is an analytical process to characterize watersheds and identify potential actions for addressing problems and concerns and to identify possible management options. It assembles information necessary to determining the ecological characteristics and behavior of the watershed and to develop options to guide management in the watershed, including adjusting riparian reserve boundaries.
- **Riparian Reserves:** Riparian Reserves define the outer boundaries of the riparian ecosystem. They are the portions of the watershed most tightly coupled with streams and rivers. They provide the ecological functions and processes necessary to create and maintain habitat for

aquatic- and riparian-dependent organisms over time, provide dispersal corridors for terrestrial organisms, and to provide connectivity in a watershed. The boundaries were interim until a watershed analyses was completed, at which time they could be modified depending on suggestions made in the watershed analyses.

- **Key Watersheds:** Key Watersheds are intended to serve as refugia for aquatic organisms, particularly in the short term for at-risk fish populations, to have the greatest potential for restoration, or to provide sources of high-quality water. Tier 1 key watersheds currently have good populations or habitat, a high restoration potential, or both. Tier 2 key watersheds provide sources of high quality water.
- **Watershed restoration:** Watershed restoration is designed to recover degraded habitat. Restoration activities focus on restoring the key ecological processes required to create and maintain favorable environmental conditions for aquatic and riparian-dependent organisms.

The ACS also includes standards and guides that apply to management activities in Riparian Reserves and Key Watersheds.

The primary objective of this chapter is to identify the expectations for the ACS in the first 10 years of implementation and to assess how well the ACS has met the expectations. Additionally, I will review the original scientific basis for the ACS and the relevant science produced since then.

Expectations and Results

Potential Listing of Fish Species and Evolutionarily Significant Units Under the Endangered Species Act

A primary motivation for developing the ACS was the anticipated listing of distinct population segments of various species of Pacific salmon, called Evolutionarily Significant Units (ESUs), and other fish species under the Endangered Species Act (ESA 1973). When the Plan was developed in 1993, only the Sacramento winter chinook salmon, the shortnose sucker, and the Lost River sucker were listed. Since then, 23 ESUs of Pacific salmon and 3 population segments of bull trout found in Plan area have been listed. Twenty units of salmon and all bull trout population segments are found on federal lands managed under the Plan (table 9-1).

Additionally, the Oregon chub was listed after the Plan was implemented and coho salmon in the Oregon Coast are currently a candidate for listing (table 9-1).

The Plan was expected to contribute to the recovery of the ESA listed fish, particularly the anadromous salmon and trout (that is, fish that spend their early life in freshwater, move to the ocean to mature, and then return to freshwater to reproduce), by increasing the quantity and quality of freshwater habitat (FEMAT 1993). It was not expected to prevent the listing of any species or distinct population segment. The primary reason for this expectation was that the federal land management agencies are responsible only for the habitat they manage; state agencies are responsible for populations on all lands and for the regulation of activities that affect populations and habitats on other ownerships. For listed ESUs of anadromous salmon and trout, factors outside the responsibility of federal land managers also contribute to the declines of these populations and will strongly influence their recovery. These factors include (National Research Council 1996):

- degradation and loss of freshwater and estuarine habitats;
- excessive harvest in commercial and recreational fisheries;

- migratory impediments, such as dams; and
- loss of genetic integrity from the effects of hatchery practices and introductions.

Ocean productivity also strongly influences population numbers of anadromous salmonids.

Conditions in the marine environment in the Plan area are highly variable over time. The oceanic boundary between cool, nutrient-rich northern currents and warm, nutrient-poor southern currents is off the coast of Washington, Oregon, and northern California (Fulton and LaBrasseur 1985) (fig. 9-1). The location of this boundary is influenced by the Pacific Decadal Oscillation (PDO), which is climatically driven and results in an oscillation between positive and negative phases every 20-30 years. This oscillation results in alternating regimes of salmon production between Pacific Northwest and more northerly areas along the Pacific coast of North America (Mantua and others 1997). During periods of high productivity, zooplankton biomass--a critical food when salmonids first enter the ocean--is greater in the productive zone than in the less productive region. Early ocean survival of anadromous salmonids and the number of adults returning to freshwater are greater during the positive phases (Mantua and others 1997). The last period of high productivity was from the late 1940s to 1977 (Mantua and others 1997). The Plan area is currently in another positive production phase, but how long the current phase that began in 2001 will last is unknown.

Population numbers of many ESA-listed salmon and trout in the Plan area, and other parts of the Pacific Northwest, have increased since the Plan was implemented. However it is not possible to discern how much the Plan has contributed to this increase. Conditions of freshwater habitats on federal lands have improved moderately under the Plan (see later discussion for more details) but

not to an extent that could account for the current increases in the numbers of returning adults. Populations in areas outside of the Plan area have shown similar, and even larger, changes.

The real contribution of freshwater habitats to the persistence and recovery of anadromous salmon and trout in the region covered by the Plan will be measured when the Pacific Decadal Oscillation moves into a less productive phase, when the persistence of anadromous salmon and trout populations depends to a larger degree on freshwater habitat (Lawson 1993) (fig. 9-2). Improvements in the quantity and quality of freshwater habitat should result in greater numbers of fish entering the ocean, thus increasing the likelihood of persistence of many populations during periods of low productivity.

Changes in Watershed Condition

The ACS was designed to improve the ecological condition of watersheds in the Plan area over an extended time (that is several years to decades). It is based on preserving key ecological processes and recognizes that periodic disturbances may be required to maintain ecological productivity. As a result, the ACS does not expect that all watersheds will be in good condition at any point in time, nor does it expect that any particular watershed will be in a certain condition through time. If the ACS and the Plan are effective, the proportion of watersheds in better condition is expected to remain the same or increase over time (Reeves and others 2004). However, the ACS does not identify a particular desired or acceptable distribution of watershed condition. It does, however, recognize that significant results from the ACS were not expected for several years or decades because it will take extended time for the condition of watersheds

that were extensively degraded from a suite of past management activities to improve (FEMAT 1993).

Large improvements in the condition of individual watersheds or changes in the distribution of conditions were not expected in the short-term (10-20 years) because this was too short a time for many watersheds to improve and that the impact of restoration efforts would not be extensive enough across the Plan area to result in discernable changes in the distribution of watershed conditions. At best, it was expected that the pattern of degradation would be slowed or halted and there may be some minor to moderate improvements in watershed condition as a result of the implementation of the ACS.

A monitoring program to determine the effectiveness of the ACS was expected to be developed and implemented within a short time of the ROD (USDA and USDI 1994b) but the Aquatic and Riparian Effectiveness Monitoring Program (AREMP) did not begin until 2000. This delay resulted from the difficulty that the relevant agencies (USDA Forest Service, Bureau of Land Management, the Environmental Protection Agency, and NOAA Fisheries) had with agreeing on an approach much less an actual program. Before 2000, two attempts were made to develop an effectiveness monitoring plan that all agencies could support. Both attempts failed because the involved parties could not agree on a common vision for the plan, a common approach to the problem or methodology. The need for three attempts to develop an effectiveness monitoring plan illustrates the struggle the ACS experienced because of differences in operating and thinking among the involved agencies. AREMP was approved by the Regional Executives in

2000, and pilot testing began that year. Components of AREMP and the rationale for them are described in Reeves and others (2004).

AREMP attempts to characterize the ecological condition of watersheds by integrating a suite of biological and physical indicators and it tracks the trend in condition of the population of watersheds over time. The condition of watersheds is evaluated with Decision Support Models using fuzzy logic (Reeves and others 2004). The relations between the selected parameters and the watershed condition used in these models were based on empirical evidence and the professional judgment of aquatic specialists from the national forests, BLM districts, management and regulatory agencies involved with the Plan, and state fish management agencies. The models were built at the province and sub-province scales to account for ecological variability.

The condition of a watershed was defined as “good” if the physical attributes were adequate to maintain or improve biological integrity, primarily for native and desired fish species (Reeves and others 2004). Also, the systems that were in good condition were expected to be able to recover to desired conditions when disturbed by a natural event or land-management activities. Scores for watershed conditions ranged from 1 to -1; it being absolutely true (based on the assumptions in the decision support model) that watershed that was in good condition if the score was 1, and absolutely false that it as in good condition if the score was -1. Reeves and others (2004) emphasized the need to recognize that condition of any watershed may vary widely naturally. For that reason, it was recognized that watersheds with little or no human activity were recognized as not necessarily being in good condition at any point in time.

The focus of AREMP is not on individual watersheds but rather on the statistical distribution of watershed conditions across the Plan area. Two hundred fifty 6th field watersheds (10,000-40,000 acres) were randomly selected from throughout the Plan area to be sampled over a five-year cycle (Reeves and others 2004). The full range of management from roadless and wilderness to intensive timber harvest and livestock grazing were found in these watersheds.

Pilot testing in AREMP to evaluate sampling protocols and to determine funding and staff requirements occurred in 2000 and 2001. Actual monitoring began in 2002, with about half of the estimated funding needed to fully implement AREMP. Monitoring continued at reduced levels in 2003 and 2004. A total of 55 (of an expected 100) watersheds were sampled in 2002 and 2003 (Gallo and others, in press). No watersheds have been resampled to permit direct estimates of change in watershed condition.

The parameters necessary to estimate watershed condition, in-channel, upslope, and vegetation, were only available for 55 watersheds, and as mentioned above, none of these have been resampled (Gallo and others, in press). Lacking the ability to assess the total changes in watershed conditions in the Plan area, Gallo and others (in press) examined changes associated with riparian vegetation and the amount of roads in the 250 watersheds selected for sampling by AREMP. They calculated partial changes in watershed condition scores based on these parameters for two periods roughly from 1994 and 2003 (fig. 9-3). The statistical distribution of these scores did not change to a statistically significant degree during this time (Gallo and others,

in press). This result is not surprising given the relatively short time period in which the ACS has been in place and that condition scores only represented a partial change.

The proportion of watersheds (of those that exhibited a change) that had a higher condition in 2003 than in 1994 compared to those with lower scores was greater than expected by chance alone ($P < 0.01$, Wilcoxon Signed-rank Test (Sokal and Rohlf 1969)). The changes in condition scores for individual watersheds are shown in figure 9-3. The condition scores of about 18 of the 250 remained the same, 161 improved, and 71 decreased between 1994 and 2003 (fig. 9-3). The average changes in scores were relatively small, 0.09 (SD 0.19) for those that increased and 0.14 (SD 0.3) for those that decreased. The decreases in watershed condition scores were not simply related to management activities; the four watersheds that exhibited the largest declines had 30-60 percent of the watershed area burned. The observed changes suggest some progress due to the ACS.

The ecological significance of this progress is not known at this point in time, however. An understanding of the relation between changes in watershed scores is not established at this time. Also, because there are multiple factors influencing watershed condition a change in score can occur from a range of combination of changes in the factors. This is certainly an area that lacks research.

The reason for the change in watershed condition scores during the first decade of the Plan was attributable primarily to changes in riparian vegetation and, more specifically an increase in the number of large trees in riparian areas. The type, size, and distribution of vegetation in riparian

and upslope areas influence the condition of aquatic ecosystems (Burnett 2001); generally, the bigger and more numerous the conifers the better the condition of the watershed. Gallo and others (in press) compared the number of trees >20-inches diameter at breast height (d.b.h.) in riparian (defined as 150 feet on both sides of the stream on the west-side of the Plan area and 90 feet on the east-side) in the ACS) and upslope areas in the 250 watersheds in 1996 shortly after the Plan was implemented and in 2002. They used the GIS layers developed by the Interagency Vegetation Mapping Project (IVMP) for Oregon and Washington and CalVeg for California, which were used to assess changes in late-successional and old-growth habitat (Moeur and others, in press). The number of large trees increased an estimated 2-4 percent during this time period, most likely the result of tree growth into the >20-inch d.b.h. category (Gallo and others, in press). Concurrently, the amount of riparian area subjected to clearcutting on federal lands in Oregon and Washington in the Plan area was one-seventh the level of harvest in 1988-1991 and even less compared to earlier periods (Gallo and others, in press). Projections of tree size on federally managed lands in the central and northern Oregon Coast range suggest that the number of large trees will continue to increase by 15-20 percent over the next 100 years under the current policy (Burnett and others, in review; Spies and others, submitted).

Roads, permanent and temporary, can significantly affect aquatic ecosystems. They can result in increased rates of erosion (Furniss and others 1991, Potondy and others 1991), which in-turn may affect populations of fish and other aquatic organisms (Quigley and Arblebride 1997, Young and others 1991) and their habitats (Buffington and others 2002, Megahan and Kidd 1972). They can also form barriers to movements and can reduce interactions within and among populations of fish, amphibians, and other aquatic organisms (Trombulak and Frissell 1999).

The condition scores of watersheds as influenced by roads generally did not change significantly since the Plan was implemented (Gallo and others, in press). Three of the watersheds that had the largest increase in condition scores had the most extensive road decommissioning efforts (Gallo and others, in press). It is likely in the other cases that the amounts of road removed from any given watershed may have been relatively small and insufficient to change the watershed condition. There were 3,324 miles of road (3.6 percent of the total road mileage) were decommissioned from 1995 to 2002 on Forest Service and BLM lands in (Baker and others, in press). An estimated 354 miles of new road were constructed during the same time (Baker and others, in press). The effect of roads on aquatic ecosystems is also a function of road location; valley bottom roads affect aquatic ecosystems more than those on ridge-tops (Wemple and others 2001). The provincial and sub-provincial models that evaluate watershed condition were varied widely in how they considered road location; some consider location while others only consider the density of roads. Modification of those that currently do not consider road location may increase their sensitivity to restoration activities.

Several miles of roads have been “improved”—that is actions were taken to reduce sediment delivery and improve stability or to allow more natural functioning of streams and floodplains which includes improvements in drainage, stabilization, and relocation (Baker and others, in press). However, the watershed condition models currently do not take this into account because road improvement data are currently not available in the federal agencies corporate data bases.

Assessment of the ecological condition of an individual watershed was done on the basis of the entire watershed which resulted in many instances in considering conditions on non-federal lands. In many of the watersheds sampled by AREMP, there were a number of different owners, each with objectives and practices that differed from those of the Plan. Watersheds with more non-federal ownership had the lowest changes in watershed condition scores (Gallo and others, in press). This influences the potential amount of change that can be expected in some watersheds and could be considered in future assessments of the effectiveness of the ACS.

One clear success of the ACS is a change in the general expectation of trends in aquatic conditions across the Plan area. There is general recognition that aquatic conditions deteriorated during the pre-Plan periods of intensive federal timber harvest and road building, and these declines were predicted to continue under many of the forest plans that the Plan amended. Several forest plans that were to be implemented before the Plan acknowledged that aquatic habitat would decline (for example, the Siuslaw NF) or have a high probability of declining (Umpqua NF, Siskiyou NF). Many of the activities that could have had negative effects on aquatic ecosystems, however, have declined under the Plan. As cited earlier, the amount of timber harvest in riparian areas decreased substantially (Gallo and others, in press).

Implementing the ACS appears also to have influenced the rate at which roads were built in the Plan area. The amount of roads decommissioned was nine times greater than the amount built between 1995 and 2002, the reverse of the trend before the Plan (Baker and others, in press). The ACS and the Plan appear to have prevented further degradation of watersheds which was likely under previous Forest Plans.

Riparian Reserves

The Riparian Reserve network established by the ACS encompasses an estimated 2.6 million acres (Baker and others, in press) and was one of the major changes from previous forest plans. Before the ACS, the riparian ecosystem was generally defined as 100 feet on either side of fish-bearing streams or some areas with high landslide risk. The Riparian Reserve network of the ACS was based on an “ecological functional” approach that identified zones of influence rather than set distances and included the entire stream network, not just fish-bearing streams.

Consequently, the riparian zone along streams was expanded to the height of two site-potential trees or 300 feet along fish-bearing streams one tree height or 150 feet along permanently flowing and intermittent non-fish bearing streams (USDA and USDI 1994b). The latter undoubtedly contributed the greatest to the increased amount of area considered as the riparian reserve. More than 800 of the more than 1100 organisms considered in FEMAT (1993) were found to be associated with the Riparian Reserve network. It was also suggested in FMEAT (1993) that the size of the riparian reserve in headwater streams be the distance equal to one-half the height of a site-potential tree but it was changed to a full tree height in the Record of Decision (USDA and USDI 1994b) to increase the likelihood of persistence of habitat for aquatic and riparian dependent organisms.

The initial Riparian Reserve network was expected to be interim and activities within them very restricted until a Watershed Analysis was completed. It appears that the interim boundaries of the riparian reserves remained intact in the vast majority of watersheds, however (Baker and others, in press). The primary reasons offered for the relatively low harvest in the Riparian Reserve were that it was difficult to justify changing the interim boundaries or that there was no compelling

justification for changing the interim boundaries. (It should be noted that harvest from the Riparian Reserve was not part of the estimates of potential timber harvest.) One reason given was that the Baker and others (in press) found that with regards to the first reason that agency personnel thought that “burden of proof was too high”. No explicit criteria were established for changing the boundaries were offered by FEMAT (1993) or the ROD (USDA and USDI 1994b), but tools available now that can help identify the more ecologically important parts of the riparian and stream network from an aquatic perspective (such as Benda and others, in prep). Because Watershed Analysis is an interdisciplinary endeavor, however, changes in the Riparian Reserve boundaries need to consider non-aquatic factors such as terrestrial and social concerns. Only a few Watershed Analyses considered these factors (such as Cissel and others 1998). The effect of the extent of the riparian reserves is probably most likely in the steeper more highly dissected landscapes, where the riparian reserves network was most extensive (FEMAT 1993).

Timber production, primarily in pre-commercial thinning, has occurred on an estimated 48,000 acres (1.8 percent of the estimated total area) of the Riparian Reserve (table 9-2). The volume of timber harvested is not known because agencies do not track it. Timber harvest was expected to occur in Riparian Reserves but no level was specified by FEMAT (1993) or the ROD (USDA and USDI 1994b). Harvest from the Riparian Reserve was not part of the estimated potential sale quantity of the Plan nor was it to count towards it. Agency personnel thought that one of the primary reasons for the limited timber harvest in the Riparian Reserve was the difficulty in changing boundaries and in determining that there would be no adverse effects from the activities (Baker and others, in press).

Watershed Restoration

Watershed restoration efforts were expected to be a catalyst for initiating ecological recovery (FEMAT 1993). It was expected that restoration efforts would be comprehensive, addressing both protection of existing functioning aspects of a watershed and restoration of degraded or compromised aspects. It was recognized that it may not be possible for restoration efforts to restore every watershed or that some would only have limited success because of the extensive level of degradation. The impact of restoration efforts were not expected to be large or to be immediately visible. At the watershed scale, it may take an extended time to observe that effect of the restoration effort. The aggregate effect of watershed restoration effort, particularly those done during the initial phases of the ACS, may not be observable at the regional scale. While it may appear that relatively large amounts of area have been restored, the reality is that this represents a small part of the total area that is degraded.

It is not possible to accurately assess the regional effect of the numerous restoration efforts undertaken as part of the ACS. Gallo and others (in press) highlight several watershed restoration efforts that were successful but their impact can not be discerned at the regional scale. The length of streams restored or made assessable to fish are also a relatively small fraction of the totals. However, the watersheds that had the largest improvement in condition scores were three that had relatively extensive road restoration programs (Gallo and others, in press). Similarly, Baker and others (in press) reported that almost 69,000 acres of riparian reserve were restored, primarily in Washington and Oregon, between 1998 and 2003. The total amount of area in riparian reserve in this area is not known but the 69,000 acres represents a relatively small part (about 2.6 percent of the estimated) of total area occupied by the riparian reserve. It is expected

that as the effect of these restoration efforts that have been implemented already and those that may occur in the future that their effect will be more discernable.

Key Watersheds

Key watersheds are intended to serve as refugia for aquatic organisms, particularly in the short-term for at-risk fish populations, have the greatest potential for restoration, or provide sources of high-quality water (USDA and USDI 1994b). Tier 1 key watersheds serve one of the first two purposes. These include 141 watersheds covering 8.1 million acres. Tier 2 key watersheds provide sources of high-quality water and include 23 watersheds covering about 1 million acres. Key watersheds were aligned with late-successional reserves as closely as possible to maximize ecological efficiency (USDA and USDI 1994b) and to minimize the amount of area in which timber harvest activities were restricted.

A primary objective for the Tier 1 key watersheds was to aid in the recovery of ESA listed fish, particularly in the short term (FEMAT 1993). Refugias that are areas of high quality habitat and contain remnant populations are a cornerstone of conservation strategies. Past attempts to recover fish populations were generally unsuccessful because the focus was on fragmented areas of good habitat in stream reaches and not on a watershed perspective (Moyle and Sato 1991, Naiman and others 1992, Williams and others 1989). Tier 1 key watersheds currently in good condition were assumed to serve as anchors for potential recovery of depressed populations. Tier 1 key watersheds that had degraded conditions that were judged to have the greatest potential for restoration and therefore become future sources of good habitat.

Key watersheds had the greater increases in condition scores than did non-key watersheds (Gallo and others, in press). More than 70 percent of the key watersheds improved while less than 50 percent of the non-key watersheds. The primary reason for this was that more than twice as many miles of roads were decommissioned in key watersheds compared to non-key watersheds. This result suggests that land management agencies appear to have recognized key watersheds as priority areas for restoration, as stated in the Record of Decision (USDA and USDI 1994b).

Key watersheds were originally selected based on the professional judgment of fish biologists from the national forests and BLM districts covered by the Plan. No formal evaluation of the potential effectiveness of the network was conducted when the Plan was developed or since it was implemented. Fish populations in need of attention are clearly identified now, and it would be useful to see if the current system is beneficial to those fish in terms of the overall distribution as well as the suitability of individual watersheds.

New techniques are now available to aid in this assessment. For example, Burnett and others (2003) have developed a process to identify the potential of a watershed or stream reach to provide habitat for coho salmon and steelhead based on topographic features. In an analysis of a portion of the northern Oregon Coast Range, areas with the highest potential to provide habitat for coho salmon, an ESA candidate species, were primarily on private lands and on public lands for steelhead, which is not a listed species. Analysis of the entire Coast Range by S. Peets of the Siuslaw National Forest (unpublished) found that about 10 percent (155 miles) of the area with the best potential to provide habitat for coho salmon was on federally managed lands. A

relatively small proportion of this habitat is found in key watersheds. Similar analyses in other areas could help determine the current effectiveness of the key watersheds.

Watershed Analyses

Watershed Analysis (WA) was intended to provide the context for management activities in a particular watershed. It was to serve as the basis for developing project-specific proposals and determining restoration needs. It was envisioned in the ROD (USDA and USDI 1994b) as analytical, not a decision making process and was to involve individuals from the appropriate disciplines. The management agencies were expected to complete a watershed analysis before activities (except minor ones) were started in key watersheds and riparian reserves (USDA and USDI 1994b). The version of WA advocated in the Plan differed from the versions of watershed analyses that were used at the time (such as the Washington Forest Practices Board 1993) in that it involved disciplines and issues other than aquatic. Since the Record of Decision (USDA and USDI 1994b), several publications have examined the watershed analysis process and framework (Montgomery and others 1995, Reid 1998), but these analyses have been primarily from an aquatic perspective.

A more comprehensive review and evaluation of watershed analyses could help improve processes and likely reduce costs while increasing the useful of the product.

Baker and others (in press) estimated that 89 percent of the watersheds (of a total of 550 watersheds) in the Plan area had completed their watershed analyses by 2003 and that some unknown proportion of them had been revised at least once. This percentage seems high, given budget and personnel constraints that the land management agencies have faced. No formal

assessment of WAs has been done but their quality and effectiveness likely vary widely. There is also the opportunity to re-examine the WA process to see if it can be conducted more efficiently and, if they consider the appropriate spatial scales, which includes not just a focus on the watershed of interest and what happens there but the context of the watershed in the basin. The latter is particularly relevant for the Plan to be implemented at a landscape scale.

Relevant New Science Information

Landscapes and Dynamic Ecosystems

The ACS was based on the best science available at the time. Much scientific literature on aquatic ecosystems, on the effects of human activities on them, and on conservation strategies for fish and other aquatic and riparian organisms has been produced since the Plan was implemented in 1994. Key science findings on the ecosystem and landscape dynamics and the range of natural variation (HRV), and on the ecological role of headwater streams are summarized here. These topics relate to ACS components and are particularly relevant to assessing the validity of the ACS components, and other parts of the Plan, and for considering future modifications. Not all of the relevant scientific literature is summarized or reviewed here. Documents that provide excellent reviews and synthesis on these and other relevant topics include Spence and others (1996), National Research Council (1996), Naiman and Bilby (1998), Gresswell (1999), and Everest and Reeves (in press).

The ACS combined ecosystem and landscape perspectives to forge a management strategy that could be applied over broad heterogeneous areas. Before the ACS was developed, much of the management and research focus for fish ecology and conservation was on relatively small spatial

scales, such as habitat units (Bisson and others 1982, Nickelson and others 1992) and reaches (Murphy and Koski 1989). At these scales, the needs of individual fish or communities are the primary interest. Williams and others (1989) found that no fish species listed under the Endangered Species Act was ever recovered after listing and attributed this failure to the general focus of recovery efforts on habitat attributes rather than on restoring and conserving ecosystems. Thus, the developers of the ACS believed that shifting the focus to larger scales was necessary to aid in the recovery of freshwater habitats of listed and declining populations of anadromous salmon and trout and other fish in the range of the northern spotted owl. Since the ROD was approved (USDA and USDI 1994b), a variety of sources, including interested citizens, interest groups, scientific review and evaluation groups (such as the Independent Multidisciplinary Scientific Team 1999, National Research Council 1996), regulatory agencies, and policy- and decision-makers have called for developing policies and practices to manage the freshwater habitats of at-risk fish at ecosystem and landscape scales.

Understanding the differences and relation between scale and ecological organization is critical to implementing and evaluating the ACS. Allen and Hoekstra (1992) proposed a framework that emphasizes the role of the observer in choosing a scale of observation and deciding how to conceptually organize the parts and processes. By **scale**, they mean spatial or temporal extent. In contrast, **organization** is a subjective or definitional construct that invokes implicit, user-defined criteria. Ecological organization, such as ecosystem, landscape, or population, has meaning without any reference to a particular scale. For real-world management issues, both scale and organization should be made explicit. The intersection of the two creates a clear conceptual boundary that allow discourse and management to proceed.

Ecosystems and landscapes are levels of organization that are especially important within the ACS. Of the two, landscapes are the most tangible in that spatial proximity is the organizing principle (Allen and Hoekstra 1992), and the components of the landscape (such as forest stands, streams, clearings, roads, and so on) are readily apparent to human observers. From an aquatic perspective, the landscape of interest can be quite large and include multiple watersheds (Reeves and others 2002, 2004) but spatial patterns (that is, landscape attributes) can also be important at smaller scales. In contrast to landscapes, ecosystems are organized around the interaction between physical and biological components. The processes and material flows that are the substance of the ecosystem organization may be difficult to observe. Reeves and others (2002) and Reeves and others (2004) used the directional flow of water to define aquatic ecosystems, and bounded their spatial extent using watersheds, defined as subbasins of 20-200 square miles by FEMAT (1993), to be the boundaries of an aquatic ecosystem.

In conventional terms, ecosystem management often refers to managing of large geographic areas, which has contributed to the confusion between ecosystems and scale. Lugo and others (1999) reiterated the major paradigms of ecosystem management, including:

- Ecosystems are not steady state but are constantly changing through time.
- Ecosystems should be managed from the perspective of resilience, as opposed to stability.
- Disturbance is an integral part of any ecosystem and is required to maintain ecosystems.

Clearly, these principles are not tied to a particular scale and would apply equally well to a single watershed as to a region.

Ecologists and managers recognize the dynamic nature of terrestrial ecosystems and how the associated biota and physical characteristics change through time. They are also aware that the range of conditions an ecosystem experiences is determined to a large extent by the disturbance it experiences (such as wildfire, hurricane, and timber harvest and associated activities). Natural disturbances can increase biological diversity, be crucial for the persistence of some organisms and the habitat that support them, and express and maintain key ecological processes (Turner and others 1994). Disturbances invariably involve a disruption in existing connections among ecosystem components, which leads to the release of nutrients and other materials and the potential for reorganization (Holling 1992). Resilience is the ability of an ecosystem to recover to after a disturbance (Lugo and others 1999). An ecosystem demonstrates resilience after a disturbance when the environmental conditions after the disturbance are within the range of conditions that the system exhibited before the disturbance. Reduced resilience may include both the extirpation of some species and increases in species favored by available habitats (Levin 1974, Hansen and Urban 1992, Harrison and Quinn 1989).

Given the role of disturbance in ecosystem dynamics, it is reasonable to expect that ecosystems to be most resilient to the types of disturbance under which an ecosystem developed. Thus, one approach to minimizing management impacts is to make the combination of management actions and natural disturbance resemble the natural disturbance regime as closely as possible (Lindenmayer and Franklin 2002). Factors considered in developing ecosystem management plans and policies include the frequency, magnitude (Hobbs and Huenneke 1992, White and Pickett 1985) and legacy (that is, the conditions and materials that exist immediately following the disturbance) (Lindenmayer and Franklin 2002, Reeves and others 1995) of disturbance

regimes in managed ecosystems. The effects of land management on the ecosystem depend on how closely the management disturbance regime resembles the natural disturbance regime with regard to these factors. Everest and Reeves (in press) report they found little evidence or studies in the peer-reviewed literature where fish populations or habitat responded positively to or remained unchanged as a result of the effects from intensive land management activities.

Landscape management strives to maintain a variety of ecological states in some desired spatial and temporal distribution. Management at that scale addresses the dynamics of individual ecosystems, the external factors that influence the ecosystems that compromise the landscape, and the dynamics of the aggregate of ecosystems (Concannon and others 1999). To do this, landscape management could consider developing of a variety of conditions or states in individual ecosystems with the landscape at any time and the pattern resulting from the range of ecological conditions that are present (Gosz and others 1999). The specific features of the ecological states and their temporal and spatial distribution will vary with the objectives for a given landscape.

Scientists and managers have worked in concert to try to develop tools and techniques to facilitate landscape management. One such approach that relies on historical range of variability (HRV), which is conditions that a level of organization experiences naturally over an extended time, several decades to centuries. The term is often used for individual components of an ecosystem, such as the number of pieces of large wood or number of pools, or for ecological states. The usual manner for establishing the HRV for a component of interest is to measure the parameter in pristine systems (systems with little or no history of effects from human activities).

The HRV is represented by the distribution of these values. This range is well established for terrestrial systems (early-, mid-, and late-successional) (for example, Wimberly and others 2000), but it is not nearly well or widely recognized for aquatic ecosystems.

Spatial scale is an important, but not well recognized, element of the historic range of variability. The HRV is generally inversely related to spatial scale (Wimberly and others 2000). The smaller the spatial scale, the larger is the HRV and, conversely, the larger the scale the smaller the HRV. Hierarchy theory provides the rationale for this relation and is an appropriate framework for considering ecosystem issues at and between different spatial scales (Overton 1977). Each level in the hierarchy of an ecosystem has unique properties and behaviors that are expressed over time. The properties of lower levels of organization are “averaged, filtered, and smoothed” as they are aggregated at higher levels of organization (O’Neill and others 1986). Consequently, the range and variability in the properties and conditions of the system are relatively wide at lower levels of organization compared to higher levels (Wimberly and others 2000). A recent paper on the concept of HRV (Landres and others 1999), and another estimating HRVs (Keane and others 2002) did not consider the effect of spatial scales.

Wimberly and others (2000) illustrated the HRV of successional vegetative stages in the Oregon Coast Range at multiple spatial scales. They estimated (based on a model of fire frequency and intensity and vegetation response over 3,000 years) that, at the scale of a late-successional reserve (100,000 acres), the range in the amount of old growth was from 0 to 100 percent. For an area roughly the size of a national forest (750,000 acres), the HRV for old-growth was from about 10 to 75 percent. The HRV for the Coast Range (5,600,000 acres) was 30-55 percent. The

large, infrequent disturbance events generally affect relatively small portions of the landscape at any one time. Thus, having the entire area observed affected by a disturbance event at the same time is highly unlikely. The asynchronous nature of the disturbance events results in a series of patches of vegetation of different ages. This narrows the HRV because of the reduced likelihood of finding the extreme conditions of the entire area either with no or all old-growth at any particular time. The HRV is further reduced at larger spatial scales because disturbance events are even more desynchronized. Consequently, the range and variability in the properties and conditions of the system are relatively wide at lower levels of organization compared to higher levels (Wimberly and others 2000).

Spatial scale and implementation problems—

The developers of the Aquatic Conservation Strategy (FEMAT 1993) and the Record of Decision (USDA and USDI 1994b) did not fully recognize the implications of shifts to the landscape scale of the Plan and the ACS and its objectives, which has led to much confusion with the ACS objectives. The land management and regulatory agencies initially attempted to meet all of the ACS objectives for any action, which led to many problems and was the impetus for the environmental impact statement (EIS) that clarified the intent of the ACS (USDA and USDI 2003). The objectives provide a framework for managing aquatic ecosystems at multiple spatial scales, but they became a checklist to evaluate the acceptability of any proposed action at the site scale. The objectives were not intended to be a hard set of criteria that could be applied equally at each spatial scale of concern. This application was technically impossible because the objectives include a range of spatial scales, and the relation among scales was not considered. For example, objectives 1, 2, and 9 (listed on page 1) deal with landscape and regional

objectives. The others deal with ecosystems. Determining consistency with the ACS at the site or small watershed scale is not as simple as assuming that all sites or small watersheds need to be in “good” condition at all times and that any actions that “degrade” a site or small watershed violates the ACS objectives. Conditions at the small scale range widely over time. The overriding objective is to have a mix of conditions at the broader scale, which requires that individual sites each exhibit a range of conditions over time.

Consistency at the small scale (site or subwatershed) is determined by the range of variability established at the larger scales (watershed or basin). The range of variability at the larger scales is the frequency distribution of conditions at the smaller scale that support acceptable amounts of habitat for populations of fish and other aquatic organisms. Watershed analysis was expected to establish the range of variability at the different scales, which was to be used to determine if proposed actions were consistent with the ACS. The focus of watershed analyses, however, has been primarily on the watershed; they fail to provide the context of the watershed in the larger landscape.

The recent supplemental EIS that clarifies the original intent of the ACS (USDA and USDI 2003) discusses the importance of considering multiple scales. Dealing with this issue is important if the ACS is to succeed.

Dynamics and aquatic ecosystems—

The perspective that aquatic systems are dynamic, particularly at the ecosystem and landscape scales, was not widely recognized and no time was left to work out the implications when the ACS was developed. Before it was developed, a small number of researchers recognized that

biotic (Resh and others 1988) and physical (Swanson and others 1988) components of aquatic systems, particularly at the smaller spatial scales, were influenced by relatively frequent events, such as floods. One reason for the absence of the recognition of dynamics of aquatic ecosystems is that the major paradigms that shape our thinking about aquatic systems, such as the River Continuum Concept (Vannote and others 1980), do not consider time or its influence. Similarly, classification schemes such as that of Rosgen (1994) identify a single set of conditions for a given stream or reach type; how these conditions may vary over time is not considered. The physical and biological relations were assumed to be fixed in time and to be unchanging. From this perspective, watershed processes were assumed to be continuous and predictable, implying that the biophysical changes along the riverine network were easily predictable and modeled (for example, Newbold and others 1982, Vannote and others 1980).

Frissell and others (1986) describe the hierarchical organization of aquatic ecosystems and identify a temporal component associated with each spatial scale; the finer the scale, the shorter the response period. However, they did not consider how features of a given level in the hierarchy respond over time. A more recent examination of the hierarchical organization of streams by Fausch and others (2002) also recognized that time is a critical factor to consider when examining aquatic ecosystems. They did not integrate time into their description of stream systems, however. The failure to incorporate time into consideration of aquatic systems, especially at higher levels of organization, has led to an implied expectation that stream ecosystems experience a limited, if not a single, set of conditions and that this condition (or conditions) is relatively stable through time.

The foundation for the ACS focus on ecological processes and dynamics came from Naiman and others (1992). They hypothesized that different parts of a watershed (headwaters, middle portion, and lower portion) had different disturbance regimes, based on the frequency and magnitude of disturbance. They also believed that the landscape would have watersheds with a range of conditions because of the asynchronous nature of large and infrequent disturbance events, such as wildfire and flooding. More recent studies have proposed that stream systems are complex networks with branched shapes rather than as linear systems, which provides a better understanding of the ecological processes that link riparian and aquatic ecosystems (Benda and others 2004, Fisher 1997). This perspective implies that aquatic ecosystems are not steady state; rather, streams are invariably dynamic where their conditions vary in space and time because of periodic events such as wildfire and large storms and subsequent floods, hillslope failures, landslides, and debris flows. The signatures of these events are most visible at tributary junctions, which also are sites of high biological diversity (Benda and others 2004).

Since the Plan was implemented, several studies examined the dynamics of aquatic ecosystems in space and time. Reeves and others (1995) described the range of conditions of watershed in the Tyee sandstones of the central Oregon coast in response to wildfire. They found a range of conditions from less productive to more productive. The most complex habitat and biologically diverse fish assemblage was found in a stream that was about 160-180 years from the last major wildfire disturbance. Simplified habitat conditions and less diverse fish assemblages were found in streams that were more recently disturbed (80-100 years) and that had not been disturbed for a longer period (300+ years). This pattern appears to have resulted from the change in amounts of wood and sediment over time. Immediately after a wildfire, channels are filled with sediments

and, as result, much of the wood is buried. The amount of sediment decreases over time because it is eroded and exported from the system faster than it is being delivered to the channel from hillslopes stabilized by forest recovery. Habitat conditions improve as the amount of sediment declines and wood increases either from recruitment or excavation. After extended times, however, sediment declines to amounts that do not support development of pools.

Headwater streams in the same region as Reeves and others (1995) exhibited a different pattern of variation in conditions over time (May and Gresswell 2004). Channels that had not been disturbed for several decades were filled with gravel and wood. Recently disturbed channels were devoid of sediment and wood and were scoured to bedrock. Benda and Dunne (1997a, b) and Benda and others (1998) described a similar distribution of in-channel sediment conditions in watersheds over time. Benda and others (2003a) examined the effects of landslides after wildfires on aquatic ecosystems in the Boise River, Idaho. The landslides significantly affected the channel, creating complex channels and delivering large amounts of wood to the channel. As was observed in the Oregon Coast Range (Reeves and others 1995), channel conditions are expected to vary widely over time. See Box 1 for further discussion on the variation among watersheds in the response to large disturbance events.

Several factors influenced the responses of these studies. The physical legacy of the disturbances was important; Wood in headwater channels accumulated gravel and began the refilling process. Wood and sediment delivered to fish-bearing streams from head water channels facilitated development of conditions favorable to fish over time. Refugia can be areas that afforded protection to individuals during the disturbance event and in the affected area or in nearby areas

that were not affected and provide sources of individuals to re-establish populations in affected areas (Roghair and others 2002, Sedell and others 1990). The life-history (Dolloff and others 1994) and habitat requirements (Reeves and others 1993, 2002) can also influence the immediate and long-term responses of a population to disturbance events.

Implications—

The dynamic view of aquatic ecosystems and landscapes just described at odds with the experience and perspectives of some in the research, management, and regulatory agencies and the public. Montgomery and others (2003) questioned the role that dynamics plays under natural conditions. They contend that the role of disturbances such as debris flows in old-growth forests is limited. They believe that models of disturbance ecology for salmonids, such as that presented by Reeves and others (1995), need to recognize differences in the disturbance dynamics of old-growth and industrial forests to “provide credible avenues for determining risk associated with land management in steep forested terrain” (Montgomery and others 2003). They believe that “management recommendations based on evolutionary interpretations that are themselves based on a disturbance model primarily applicable to industrial forests may prove misleading” (Montgomery and others 2003).

Clearly, obstacles remain in the path towards a fully implemented ACS that is consistent with the vision articulated in FEMAT (1993) and the ROD (USDA and USDI 1994b). Experience has shown that the ACS accommodates an alternative management model to site-specific standards and guides. Reeves and others (1995, 1998, 2002) presented an example for the Oregon Coast

Range. Another example was for the central Oregon Cascade Mountains (Cissel and others 1998). Progress could be facilitated by attention to several pressing issues.

Focusing policies for and management of aquatic ecosystems at the landscape scale presents challenges to policy makers, managers, and regulators (Reeves and others 2002). A fuller exposition of the historic range of variability would provide a richer understanding of how the conditions of aquatic ecosystems vary through time at all spatial scales and the ecological, social, and economic implications of this variation. Currently, the historical range of the conditions of aquatic ecosystems is assumed to be small and, generally to be good for habitat. Many managers, regulators, and interested citizens expect aquatic conditions to be relatively constant through time and to be present on all systems at the same time. More realistic expectations would aid both implementing and assessing the ACS.

The interaction of multiple processes operating at multiple spatial and temporal scales is difficult to understand, and even more difficult to incorporate into a coherent management strategy.

Understanding the relation among different spatial scales is necessary to successfully assess the effects of management policies and activities on aquatic ecosystems in the future. The challenge is to develop a process that not only looks at current aquatic conditions but also:

- Looks broadly to determine the large context;
- Looks historically to assess past trajectories of the systems and natural history; and
- Looks ahead to identify potential threats and expectations.

This perspective would allow for a more integrated response to basic questions, where are we, where do we want to go, how we get there. Watershed assessment is a logical forum to explore these questions.

The failure to recognize the landscape focus of the ACS has precluded consideration of potential options for different management practices and policies. Some practices and policies for managing aquatic ecosystems under the Plan are in many ways similar to those before the Plan. For example, cumulative effects are still determined at the 6th to 7th field watershed scale. Thus, management activities are dispersed among watersheds to avoid potential negative effects (fig. 9-4A). But this approach is not necessarily consistent with the landscape focus of the ACS. A potential alternative option was offered by Reeves and others (1995). They suggested that management activities be concentrated in a given watershed for an extended period (fig. 9-4B), rather than dispersed over wider areas. Grant (1990) modeled both scenarios to determine their effects on the pattern of peak flows and found little difference between the two. Concentrating rather than dispersing activities may also confer benefits to terrestrial organisms that require late-successional forests (Franklin and Formann 1987).

Specifying the spatial scale is important when range of natural variation and cumulative effects are discussed or evaluated. At small scales, the historic range of variability is very large; so, except from the most extreme impacts, no cumulative effects may result from management actions. Most assessments of the effects of human activities are made at relatively small scales. Failure to recognize the relation between space and HRV undoubtedly contributed to the current confusion about the ACS and the scales at which it is applied, and how compliance is measured.

The view of aquatic ecosystems as dynamic entities has implications for the network of key watersheds and the potential long-term success of the ACS. First, an underlying assumption about key watersheds was that streams in old-growth forests contained the best habitats for fish. Many of the key watersheds in Option 9 of FEMAT (1993) were associated with late-successional reserves. Reeves and others (1995) suggested that streams in mid-successional forests were more productive than those in old-growth forests in the Oregon Coast Range. Whether this pattern is found in other areas is not known at present and could be a future research emphasis. The second implication of treating aquatic ecosystems as dynamic entities deals with the expectations of reserves in dynamic landscapes. Reserves in such a setting cannot be expected to persist for long periods. How future key watersheds will develop and where in the landscape they will occur are key questions for managers, regulators, and researchers to consider.

Riparian Reserves

Ecological functions and distance—

The generalized curves (fig. 9-5) developed in FEMAT (1993) were developed by examining the available scientific literature about key ecological processes in riparian ecosystems. The effects of riparian vegetation decreased with an increasing distance from the streambank (FEMAT 1993). Generally, most ecological processes occurred within 100 feet (about 2/3 the height of a site-potential tree) (fig. 9-5).

An exception was large wood (fig. 9-3a). Large wood provides a crucial ecological function (see Bilby and Bisson 1998, Spence and others 1996) in aquatic ecosystems in the Plan area and is

readily acknowledged by land management and regulatory agencies. In developing the generalized curve for wood sources, trees were assumed to reach a stream from a slope distance equal to the height of the tree (FEMAT 1993). Implicit in this assumption, but unstated by FEMAT (1993), was that trees in the riparian zone farthest from the channel would not immediately be in the current stream channel. These trees could either be recruited over time to the channel or, with wide valley floors, the channel would migrate over time and such pieces could then be in the channel. Bilby and Bisson (1998) noted that the latter process may be an important source of wood for streams in some areas.

Recognition of the role and importance of downed wood in riparian areas has increased since the ACS was implemented. Downed wood, particularly larger pieces, provides required high-moisture microhabitats for many riparian-associated amphibians (Pilliod and others 2003). It also provides habitat for several species of birds and small mammals found in riparian areas (Kelsey and West 1998). And downed wood may collect and impede the movement of finer sediments into streams, preventing fine sediment from reaching streams where they can affect habitat conditions and biota (See references in McIver and Starr (2001), Wondzell and King (2003)). This effect may be particularly important in areas where chronic overland erosional processes dominate, which are very rare in the Plan area except after intense fire or severe management disturbance. Trees in the riparian area farthest from the channel are sources of this downed wood.

Microclimate conditions in riparian areas was another ecological function in addition to wood sources that occurred beyond 100 feet (a distance of about 2/3 of the height of a site potential

tree) (fig. 9-5b). Based on the work of Chen (1991), the developers of the ACS (FEMAT 1993) argued wider buffers may be needed to maintain interior microclimatic conditions. Subsequent work by Brosfokske and others (1997) supported this contention. Maintaining favorable microhabitat conditions in riparian areas is also important for wildlife species (Kelsey and West 1998).

Headwater streams—

The Riparian Reserve was one of the cornerstones of the ACS. The Riparian Reserve network included fish-bearing streams, which had been the focus of management of aquatic ecosystems before FEMAT, as well as small, fishless headwater streams. The latter generally comprise 70 percent or more of the stream network (Gomi and others 2002). Before the ACS these streams were not widely recognized as part of the aquatic ecosystem but knowledge about and recognition of the ecological importance of headwater streams has increased since then. They are sources of sediment (Benda and Cundy 1997a, b; Zimmerman and Church 2001) and wood (Reeves and others 2003) for fish-bearing streams. They provide habitat for several species of native amphibians (Kelsey and West 1998) and macroinvertebrates (Meyer and Wallace 2001), including recently discovered species (Dieterich and Anderson 2000), and may be important sources of food for fish (Wipfli and Gregovich 2002). Small streams are also storage and processing sites of nutrients and organic matter, important components of the energy base for organisms used by fish for food (Kiffney and others 2000, Wallace and others 1995, Webster and others 1999, Wipfli and Gregovich 2002).

Headwater streams are among the most dynamic portions of the aquatic ecosystems (Naiman and others 1992). Tributary junctions between headwater streams and larger channels are important nodes for regulating material flows in a watershed (Benda and others 2004, Gomi and others 2002) and are the locations where site-scale effects from management activities are often observed. These locations have unique hydrologic, geomorphic, and biological attributes. The movement of sediment, wood, and other materials through these locations results in sites of high biodiversity (Johnson and others 1995, Minshall and others 1985). Habitat in these sites may also range from simple to complex, depending on time from the disturbance (such as landslides and debris flows) and the types and amount of materials delivered to the channel.

Large wood is an important element of stream and river ecosystems. It forms and influences the size and frequency of habitat units for fish and other organisms that depend on aquatic and riparian habitats (Bilby and Bisson 1998, Bilby and Ward 1989, Wallace and others 1995). The size of pieces and amount of wood in the channel also influences the abundance, biomass, and movement of fish (Fausch and Northcote 1992, Harvey and Nakamoto 1998, Harvey and others 1999, Murphy and others 1985, Roni and Quinn 2001). Wood enters streams via chronic and episodic processes (Bisson and others 1987). Chronic processes, such as tree mortality and bank undercutting (Bilby and Bisson 1998, Grette 1985, Murphy and Koski 1989), generally introduce single pieces or relatively small numbers of trees at frequent intervals. Episodic processes usually add large amounts of wood to streams in big but infrequent events, such as wind throw (Harmon and others 1986), wildfire (Agee 1993), severe floods, and landslides and debris flows (Keller and Swanson 1979, May 2002, Reeves and others 2003).

Examinations of wood sources in streams (such as McDade and others 1990, Murphy and Koski 1989, Robison and Beschta 1990) have focused until recently on chronic input from immediately adjacent riparian zone. Such studies found that the most of the wood found in streams was derived from within a distance equal to about 100 feet. Riparian management in forest plans developed before the Plan was based primarily on these cited studies and assumed that most of the wood found in streams came from within 100 feet of the stream. The studies on which this assumption was made, however, either did not consider episodic sources of wood (such as Van Sickle and Gregory 1990) or did not sample study reaches influenced by upslope sources (such as McDade and others 1990). The assumption that all wood came from within 100 feet of the channel based in the cited studies is incorrect and contentions about the potential effectiveness of plans and policies based on it are questionable.

In steep terrain, which is found on much of the Plan area, landslides and debris flows are potentially important mechanisms for delivering sediment and wood from hillslopes and small headwater channels to valley-bottom streams. Reeves and others (2003) found that an estimated 65 percent of the number of pieces and 46 percent of the total volume of wood in a pristine watershed in coastal Oregon came from outside the riparian zone immediately adjacent to the fish-bearing stream. More than 80 percent of the total number of pieces of wood in a western Washington stream (Benda and others 2003a) and a northern California stream (Benda and others 2002) were from upslope sources. Other studies, such as May (2002) and Benda and others (2003b), found large amounts of wood from upslope sources in streams in the Oregon Coast Range and Idaho, respectively.

Pieces of large wood delivered from upslope areas are generally smaller than those originating from the riparian zones along fish-bearing streams. Reeves and others (2003) found that the mean volume of a piece of large wood from upslope areas was one-third the mean size of pieces from stream-adjacent riparian areas in a coastal Oregon stream. Differences in mean size is likely attributable to fire history and other stand-resetting events. Hillslopes are more susceptible to fire and burn more frequently than streamside riparian zones (Agee 1993). Thus, trees in the streamside riparian zone may be disturbed less frequently and achieve larger sizes than upslope trees.

Geomorphic features of a watershed influence the potential contribution of upslope wood sources. Steeper, more highly dissected watersheds will likely have a greater proportion of wood coming from upslope sources than will watersheds with lower gradients. Murphy and Koski (1989) and Martin and Benda (2001) found that upslope sources of wood comprised a relatively small proportion of the total wood in streams that they examined in Alaska. The watershed studied by Martin and Benda (2001) had a wide valley floor so wood was deposited along valley floors, away from the main channel. In contrast, Benda and others (2003b) found that wood delivered in landslides after wildfires was deposited in wide valley reaches in the Boise River, Idaho. In a central Oregon coast stream, Reeves and others (2003) found that the amount of upslope derived wood was greatest in reaches with narrow valley floors.

Even in watersheds where the potential contribution from upslope sources of wood is high, the ability of individual upslope sources to contribute wood to fish-bearing streams can vary widely. Benda and Cundy (1990) identified the features of first-and second-order channels with the

greatest potential to deliver sediment and wood to fish-bearing streams in the central Oregon Coast. The primary features were gradients of 8-10 percent with tributary junction angles of $<45^\circ$. These features can be identified from Digital Elevation Models (DEMs) and topographic maps. Benda and others (in press) have developed a process that uses information from the DEMs to develop basin-specific information for stratifying landscapes for varying intensity of resource management, identifying ecologically significant terrain for conservation, and prioritizing watershed and in-stream restoration and monitoring activities.

The presence of large wood from headwater streams influences the behavior of landslides and debris flows and the response of the channel to such events. Large wood in debris flows and landslides influences the runout length of these events (Lancaster and others 2003). Debris flows without wood move faster and longer distances than those with wood, and they are less likely to stop high in the stream network and to reach fish-bearing channels. A debris flow without wood is likely to be primarily a concentrated slurry of sediments of varying sizes that can move at relatively high speeds over long distances scouring substrate and wood from the affected channels. These types of flows are more likely to negatively affect fish-bearing channels rather than have potential favorable effects that result from the presence of wood. They can further delay or impede the development of favorable conditions for fish and other aquatic organisms.

Over time, headwater depressions and channels are filled with material from the surrounding hillslopes, including large wood that falls into these channels, forming obstructions behind which sediments accumulate (Benda and Cundy 1990, May and Gresswell 2004). These areas are evacuated following a landslide or debris flow. This cycle of filling and emptying results in a

punctuated movement of sediment and wood to larger, fish-bearing streams (Benda and others 1998), which is—at least, in part—responsible for the long-term productivity of many aquatic ecosystems (Benda and others 2003b, Hogan and others 1998, Reeves and others 1995). The absence of wood to replenish the refilling process may result in a chronic movement of sediment to larger channels, which could lead to those channels developing different characteristics than those that occurred before forest management. Such conditions could be outside the range of watershed conditions to which native biota are adapted (Beschta and others 2004).

Fire and riparian and aquatic ecosystems—

The issue of fire and aquatic ecosystems was given little consideration by the Aquatic Conservation Plan's developers (FEMAT 1993), primarily because the potential threat of fire to aquatic ecosystems was not widely recognized at that time. Since then, numerous studies have examined the effect of fire on upland ecosystems but relatively few examined aquatic and riparian ecosystems. Those studies that considered riparian areas generally focused on perennial streams, and the specific results vary with geographic location. In general, the frequency and magnitude (following the definitions of Agee 1993) of fires in riparian areas is less than in adjacent upslope areas. Differences between fire effects on riparian and upland areas are less in regions with more frequent and less severe fires compared to locations where the fire return interval is larger and the fires are more severe. Fire in riparian areas along intermittent streams has not been studied, most likely because the inclusion of these areas as part of the riparian systems is only recently beginning to be recognized. Assuming that the effects of fire on the riparian zones of ephemeral and intermittent streams are similar to fire effects on upland plant

communities is probably safe, however, we acknowledge that much additional research is needed.

Wildfire can profoundly affect watersheds and streams and associated aquatic organisms. The immediate effects of severe fires that burn through riparian areas and across small streams may include high mortality or emigration of fishes and other organisms caused by direct heating and changes in water chemistry (Minshall and others 1997, Rieman and Clayton 1997, Spencer and others 2003). Subsequent effects associated with the loss of vegetation and infiltration capacity of soils may include increased erosion, changes in the timing and amount of runoff, elevated stream temperatures and changes in the structure of stream channels (Benda and others 2003b, Wondzell and King 2003). The nature of these changes depends on the extent, continuity and severity of the fire, and on lithology, landform, and local climate (Luce, in press; Rieman and Clayton 1997; Swanson and others 1988). A severe fire burning through dense fuels can produce extensive areas of hydrophobic soils (DeBano and others 1998). If a large storm follows in steep, highly dissected terrain, the result can be massive erosion and debris or hyper-concentrated flows that completely reorganize entire segments of mountain streams and deposit large volumes of sediment in lower gradient reaches (Benda and others 2003b).

Whether fire is viewed as ecologically catastrophic, however, is a matter of context and scale. Following the Boise fire in central Idaho, most fish populations rebounded quickly, in part through dispersal from unburned stream refugia (Rieman and Clayton 1997). Roughly 10 years after the disturbance, little evidence remains to suggest that the distribution and abundance of

fishes in these streams are fundamentally different from similar-sized unburned streams (B. Rieman unpublished data). Beneficial effects of fire, such as increased primary productivity and invertebrate abundances, may offer mechanisms for individual fish to cope with potentially stressful conditions (such as high temperatures) in disturbed streams. Further, on time scales of decades to millennia, large disturbances have been common in these landscapes. Fishes and other species probably evolved mechanisms such as dispersal and plasticity in life history that allow them to recover (Dunham and others 2003, Reeves and others 1995).

Additionally, physical complexity in a stream may increase after a wildfire. Recent work has shown that fire and subsequent hydrologic events can contribute wood and coarse sediment necessary to create and maintain productive in-stream habitats (Bisson and others 2003, Reeves and others 1995). Benda and others (2003b), for example, have shown how mass erosion and deposition at tributary junctions can produce important heterogeneity in channel structure. Natural disturbances interacting with complex terrain has been linked to a changing mosaic of habitat conditions in both terrestrial and aquatic systems (Bisson and others 2003, Miller and others 2003, Reeves and others 1995). This variation of conditions in space and time may be the key to evolving and maintaining biological diversity and ultimately, the resilience and productivity of many aquatic populations and communities (Bisson and others 2003, Dunham and others 2003, Poff and Ward 1990).

Land managers may view salvage logging after wildfire as a potential restoration technique by which they can respond to the perceived adverse effects of fire (McIver and Starr 2001).

Research on the effects of post-fire salvage logging on terrestrial organisms has shown mixed

results; some organisms showed no effect, others increased (such as, Blake 1982, Haim and Izhaki 1994), and others declined (Saab and Dudley 1998). Studies on the potential effects of fire and post-fire logging of riparian systems and associated biota are lacking, however. Reeves and others (in review) argue that salvage logging in riparian zones may, among other things, reduce the amount and size of wood delivered to stream channels. This reduction may have immediate and long-term ecological consequences for trophic inputs and physical habitats of streams. Activities associated with salvage logging, including building new roads or opening old ones, may further exacerbate the effects of salvage logging by increasing erosion and fragmentation of the stream network. Although, in some circumstances, concerns about human safety justify salvage logging in a riparian zone, there is presently a paucity of evidence of scientific support for salvage logging in riparian zones (Reeves and others, in review). This certainly is an area worthy of future research.

“Cultural shifts” within the land management agencies—

Implementation of the Plan and ACS brought major changes to the way the affected agencies viewed and managed aquatic resources and watersheds. It is difficult to accurately describe or to quantify these changes but conversations with agency personnel find that the vast majority believe that the changes were the most important effect of the Plan and ACS. The ACS replaced local plans that contained a variety of management directions and objectives with a common framework for managing aquatic and riparian resources on public lands. Additionally, it required a more comprehensive approach to the management of aquatic and riparian resources and much more interaction with disciplines that previously they had little interaction with. Table 9-3 summarizes these changes in agency culture, analysis, and analytical basis of management. In the

view of many of the people responsible for the implementation of the ACS, these changes clearly are the primary successes of the Plan.

In a survey authorized by the Forest Plan Revision Board of Directors of Forest Service Region 6, personnel involved with the implementation of the ACS (forest and district fish biologists, hydrologists, and wildlife biologists) believed that ACS was appropriate and that it has led to improved and proactive management of aquatic resources (Heller and others 2004). The respondents also believed that there was a need to develop a single unified regional ACS and this was accepted by the Board of Directors. A single framework is currently being developed for USDA Forest Service Region 6 with the Plan ACS as its cornerstone.

Summary and Considerations

Producing a quantitative assessment of the ACS of the Plan continues to be challenged by issues of data availability and quality. First, the accuracy and quality of data on some activities is questionable. For example, Baker and others (in press) report in their summary that the FS and BLM reported decommissioning 295 miles of road. When they examined 89 watershed assessments done between 1999 and 2003, they found that road mileage in those watersheds was reduced by 1,179 miles. Data on important indicators of effectiveness, such as miles of streams with water quality problems (that is 303d-listed streams) on federally managed lands and volume of timber harvested in riparian reserves, are not available. Watershed degraded by management activities before the Plan was implemented were expected to take several years or decades to recover (FEMAT 1993). Thus, it is not too late to assemble credible data on activities and actions done under the auspices of the ACS. Field units are improving watershed conditions by

removing and improving roads, in-channel restoration projects, improving riparian areas, and so forth, in addition to providing some timber volume from the riparian reserve network. The land management agencies could consider requiring field units to report uniformly on selected key activities and have the data assembled and accessible in a central location. The availability of such data would allow for at least a more defensible qualitative assessment of the effectiveness of the ACS.

The ACS met its expectation that watershed condition will begin to improve in the first decade of the Plan. The conditions of watersheds in the Plan appear to have improved slightly since the Plan was implemented. The proportion of watersheds whose conditions improved was significantly greater than those that declined. A primary reason for this improvement was an increase in the number of large trees in riparian areas and a decrease in the extent of clearcut harvesting in riparian zones. This general trend of improvement should be expected to continue, and may actually accelerate in the future, if the ACS is to be implemented in its current form. It is highly likely that these trends would have been the reverse under many of the forest plans that were in place before the ACS.

Science information developed since the Plan was implemented supports the framework and components of the ACS, particularly for the ecological importance of smaller, headwater streams. Also, a growing body of science about the dynamics of aquatic and riparian ecosystems could provide a foundation for developing new management approaches and policies. Scientifically based tools for aiding Watershed Analysis are also available and could be considered for use by the various agencies.

One of the main topics that could be examined and considered in more detail is that of the relation between spatial scales that are considered by the Plan and the ACS. The Plan and ACS changed the focus of the land management agencies from small spatial scales (i.e., watersheds) to larger scales (i.e., landscapes). It appears that the implications of doing this have not been fully recognized or appreciated by the land management or regulatory agencies and created confusion with the public and policy makers. This has precluded the consideration of new options and approaches to management. A rigorous examination of this issue would certainly be worthwhile.

9-1—Evolutionarily Significant Units (ESUs) of Pacific salmon and trout (*Oncorhynchus* spp.), Distinct Populations Segments (DPSs) of bull trout (*Salvelinus confluentus*), and fish species listed and candidates for listing (*) under the Endangered Species Act that occur in the area covered by Plan

Species	ESU/DPS	National Forests and BLM Districts were occur
Coho Salmon	Lower Columbia/Southwest Washington	Gifford Pinchot NF, Mt. Hood NF
	Oregon Coast*	Siuslaw NF, Umpqua NF, Siskiyou NF, Eugene BLM, Coos Bay BLM, Medford BLM, Roseberg BLM, Salem BLM
	Southern Oregon/ Northern California	Rogue River-Siskiyou NF, Six Rivers NF, Shasta-Trinity NF, Klamath NF, Mendocino NF, Arcata BLM, Kings Range NCA, Redding BLM, Medford BLM, Coos Bay BLM
	Central California Coast	Ukiah BLM
Chinook Salmon	Puget Sound	Mt. Baker-Snoqualmie NF, Olympic NF, Gifford Pinchot NF
	Lower Columbia	Gifford Pinchot NF, Mt. Hood NF, Salem BLM
	Upper Columbia	Okanogan NF, Wenatchee NF
	Upper Willamette	Mt. Hood NF, Willamette NF, Eugene BLM, Salem BLM
	California Coastal	Six Rivers NF, Mendocino NF, Arcata BLM, Kings Range NCA, Ukiah BLM
	Sacramento River Winter-	Mendocino BLM

	run	
	Central Valley Spring-run	Shasta-Trinity NF, Mendocino BLM, Redding BLM
	Central Valley Winter-run	Redding BLM
Chum Salmon	Hood Canal Summer	Olympic NF
	Columbia River	Salem BLM
Steelhead	Lower Columbia	Gifford Pinchot NF, Mt. Hood NF, Salem BLM
	Mid-Columbia	Gifford Pinchot NF, Mt. Hood NF, Wenatchee NF
	Upper Columbia	Wenatchee NF, Okanagon NF
	Upper Willamette	Willamette NF, Salem BLM, Eugene BLM
	Northern California	Six Rivers NF, Mendocino BLM, Arcata BLM, Ukiah BLM, Kings Range NCA
	Central California Coast	Arcata BLM, Kings Range NCA
	Central Valley, California	Shasta-Trinity NF, Mendocino BLM
Coastal Cutthroat Trout	Southwest Washington/ Columbia River	Gifford Pinchot NF
Bull Trout	Klamath River	Winema NF
	Columbia River	Deschutes NF, Gifford Pinchot NF, Mt. Hood NF, Wenatchee NF, Okanagon NF, Willamette NF, Eugene BLM
	Coastal-Puget Sound	Gifford Pinchot NF, Mt.

Baker-Snoqualmie NF,
Olympic NF

Oregon Chub

Willamette NF, Umpqua NF

Lost River sucker

Winema NF

Shortnose sucker

Winema NF

Table 9-2—Estimated area of riparian reserve in which silvicultural activities have occurred during the first ten years of the Plan

Administrative unit	Time period	Treatment		Total
		Pre-com. thin	Regeneration harvest	
<i>Acres</i>				
USDA Forest Service				
Region 6				
Mt. Baker-Snoqualamie	1994-2000	1,100	0	1,100
Okanogan-Wenatchee	1994-2000	875	300	1,175
Gifford-Pinchot	1994-2004	600	0	600
Olympic	1994-2004	1,100	1,100	2,200
Mt. Hood	1998-2004			1,200 ^a
Deschutes	1997-2004	700	0	700
Willamette	1994-2004	6,600	125	6,725
Siuslaw	1994-2004	1,285	12,570	13,855
Umpqua	1994-2004	2,200	300	2,500
Siskiyou-Rogue River	2000-2004	1,902	0	1,902
Fremont-Winema	2003	400	0	400 ^b
Estimated total		16,762	14,395	32,357
Region 5				
Klamath	1994-2004	4,598	781	5,379
Shasta-Trinity	1994-2004	1,701	515	2,216
Six Rivers	1994-2004	3,288	516	3,804
Mendocino	1994-2004	0	0	0
Estimated Total		9,587	1,812	11,399
Bureau of Land Management (BLM)				
Oregon-Washington				
Salem	1995-2003			797 ^b
Coos Bay	1995-2003			1,326 ^b
Eugene	1995-2003			520 ^b
Roseburg	1995-2003			827 ^b
Medford	1995-2003			663 ^b
Estimated Total				4,133
California				
Arcata	1995-2004	84	0	84
Ukiah	1995-2004	0	0	0
Estimated Total		84		84
Estimated Total				47,973

^a Estimate was of 100-200 acres/year with no breakdown of treatment type.

^b No breakdown of treatment type provided.

Table 9-3—Changes in paradigms for managing aquatic and riparian resources that occurred as result of the implementation of the Plan and ACS

New	Old
Management activities should contribute to, or not retard, attainment of ACS objectives.	Management activities can occur unless unacceptable adverse impacts can be shown likely to occur.
There is a consistent strategic approach for the protection and restoration of aquatic and riparian dependent resources across the entire Plan area.	There is a variety of individual approaches for the protection and restoration of aquatic and riparian dependent resources. These are often different between administrative units for no apparent reason.
Management focus is on process and function of whole watersheds. Special efforts are made to consider and coordinate activities on all ownerships.	Focus is on the condition of individual streams or stream segments or sites. Attention is focused primarily on public land.
There is a formal program, with consistent protocols, to monitor effectiveness of the Strategy across the Plan area. Data can be summarized and analyzed for the Plan area.	Effectiveness monitoring is highly variable between administrative units. Protocols are inconsistent and preclude summarization and analysis across the Plan area.
The emphasis is to coordinate the activities of Federal agencies in the implementation and evaluation of the Plan. Special efforts are made to include all stakeholders.	Federal agencies generally work independently. Coordination is often infrequent and driven by “problems.” Efforts to involve all stakeholders occur but are not the norm.
There is a multi-scale analysis of ecosystem form and function prior to formulating proposed actions.	Proposed actions came from “target” generally unrelated to ecosystem characteristics. Analysis is generally single disciplinary, single scale, and non-collaborative.

Source: Heller 2002.

Figure List

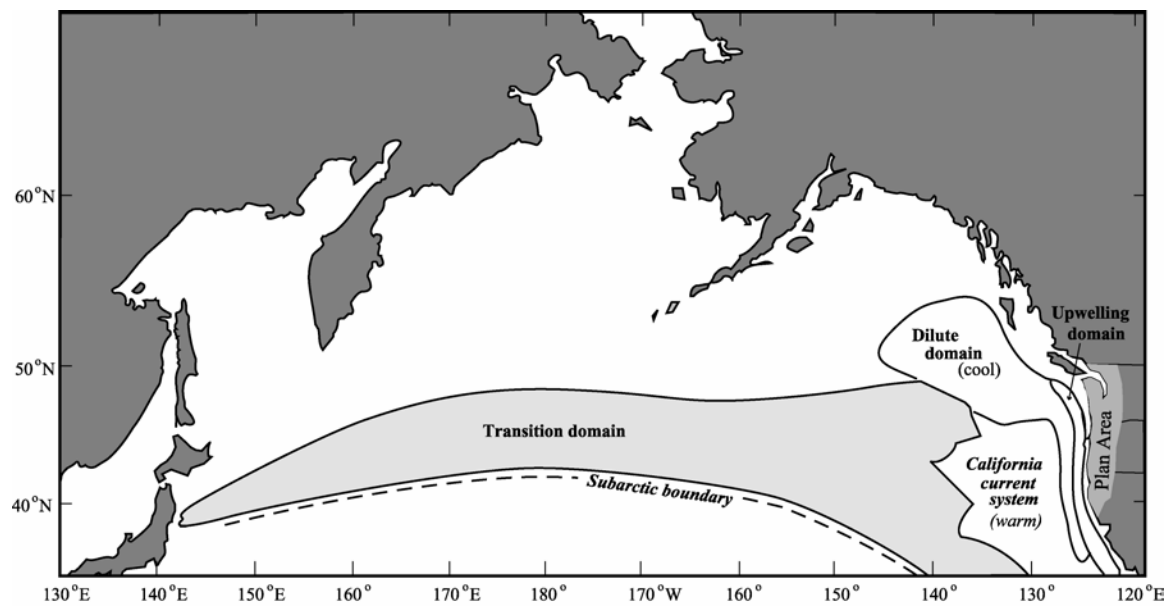
Figure 9-1—Location of boundaries of eastern north Pacific Ocean currents.

Figure 9-2—Conceptual relation between the quality of freshwater habitat, variable ocean conditions, and the persistence of populations of anadromous salmonids. “a” is the trajectory of habitat quality over time. Dotted line represents possible effects of improvement in habitat quality. “b” is the generalized time series of ocean productivity over time. “c” is the sum of the interaction of a and b.

Figure 9-3—Changes in conditions scores for 250 watersheds sampled as part of the aquatic and riparian effectiveness monitoring program of the Plan.

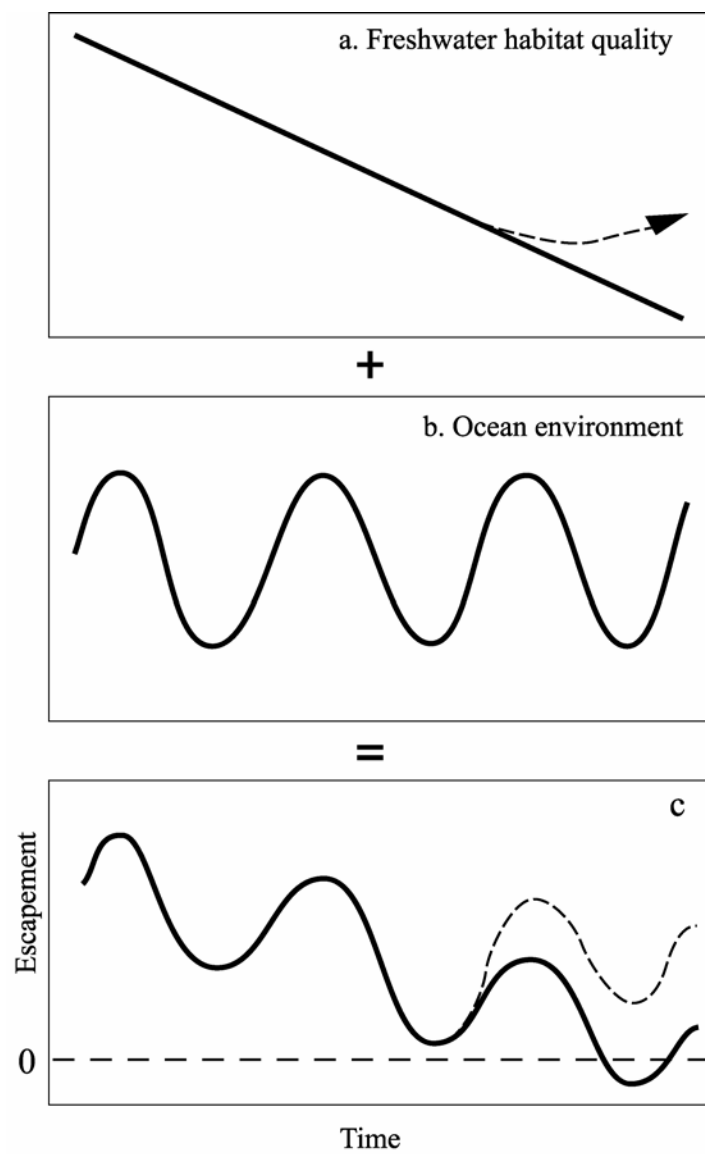
Figure 9-4—Potential approaches to watershed (a) and landscape (b) management.

Figure 9-5—Generalized ecological functions in riparian zones as a distance from the stream.



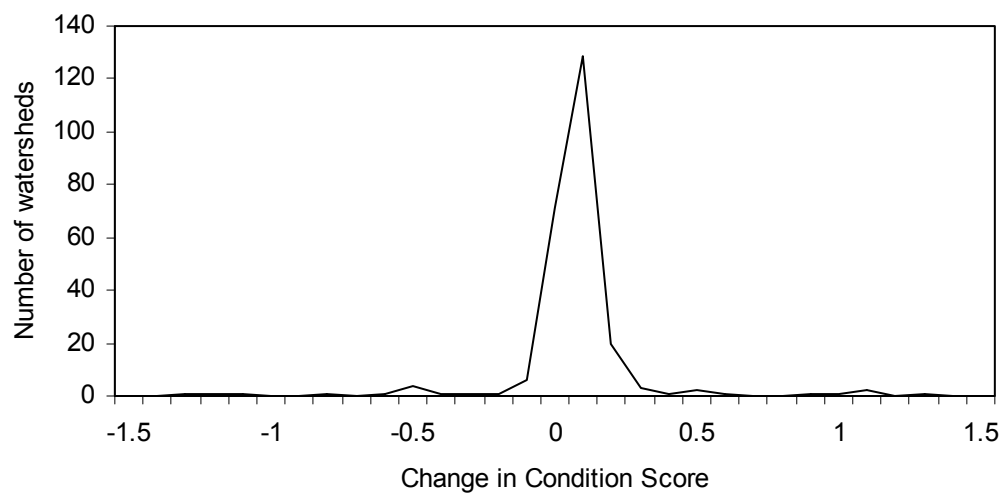
F 9-1

Source: Fulton and LaBrasseur 1985.



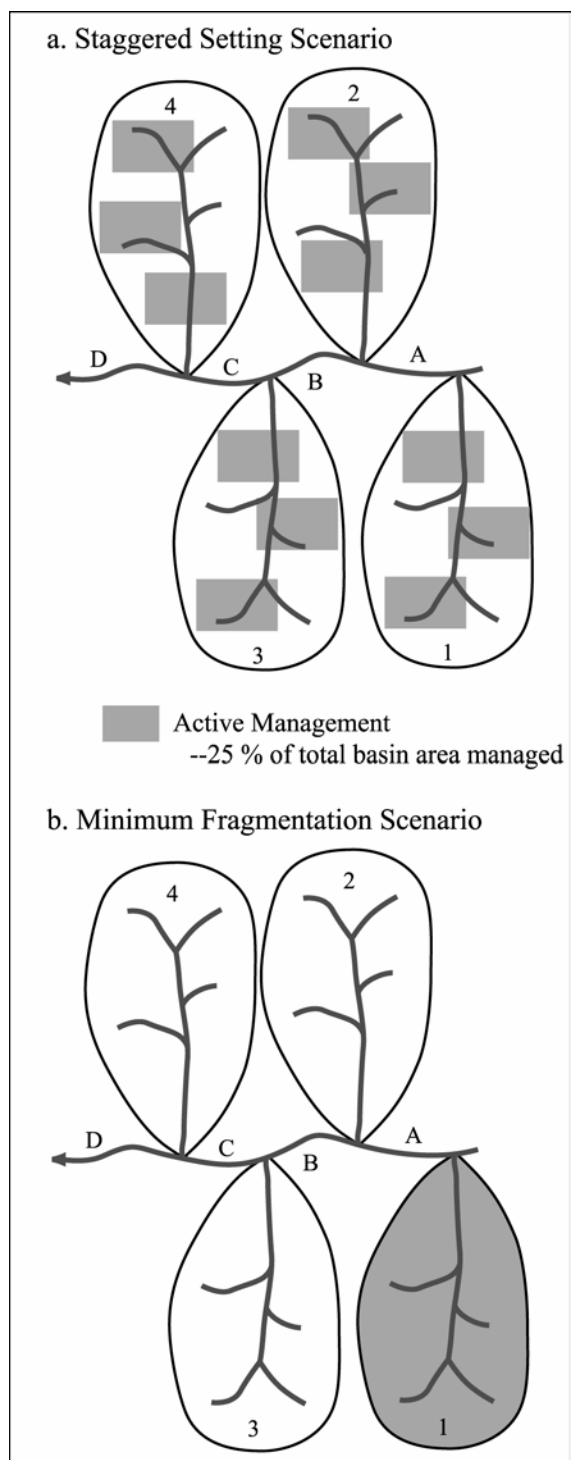
F 9-2

Source: Modified from: Lawson 1993.



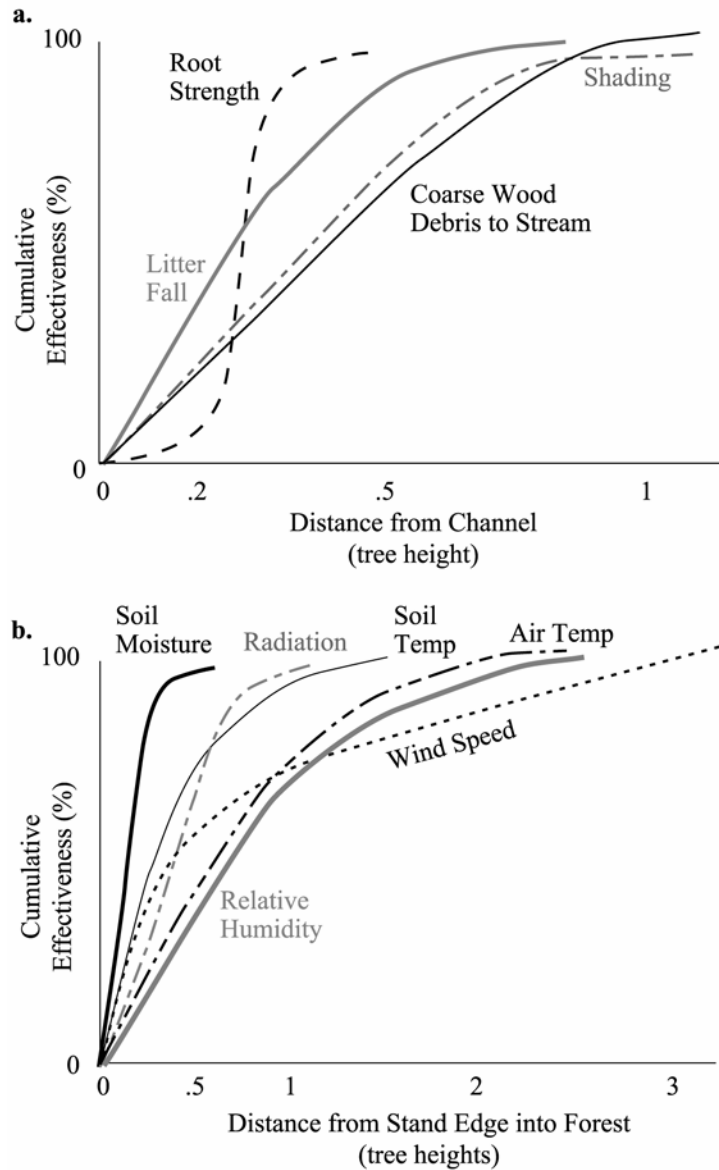
F 9-3.

Source: Gallo and others, in press.



F 9-4

From: Grant 1990.



F 9-5

Source: FEMAT 1993.

Box 1—Variation in susceptibility to and response of watersheds in the Northwest Forest Plan area to natural disturbances. Figures from L.E. Benda.

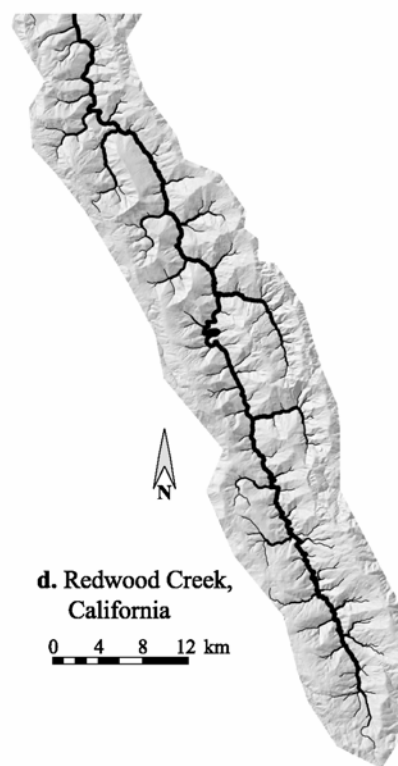
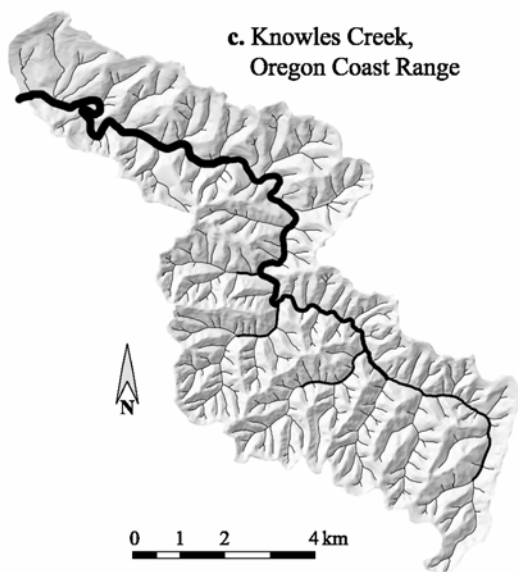
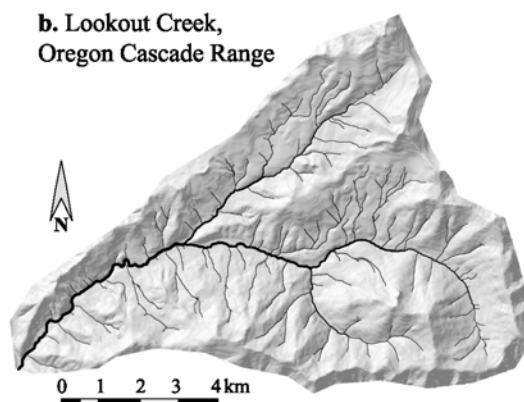
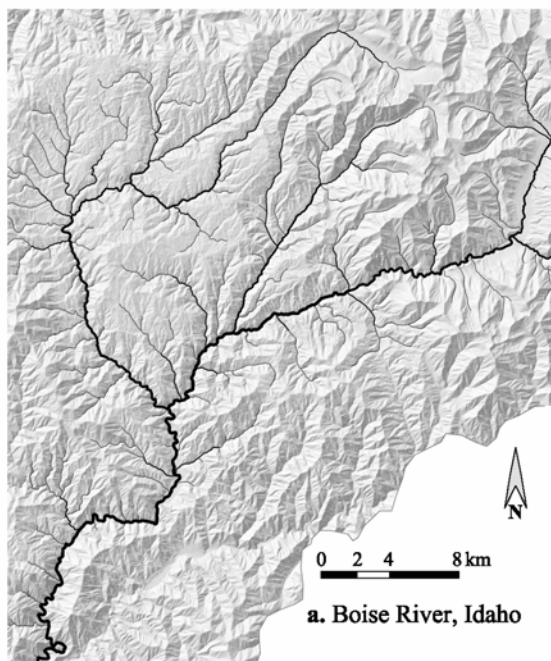
The recognition that dynamic processes, such as periodic large disturbances, have strong impacts on aquatic ecosystems represents a relatively new perspective (for example Naiman and others 1992, Resh and others 1988). Moderate to large-scale fluctuations in the movement and storage of sediment and wood during these events can create habitats and features that have long-term implications system productivity (Benda and others 2003a). There is wide variation in the response of aquatic ecosystems to given disturbance events depending on the the frequency and magnitude of the disturbance event and a watershed's local topography, channel type (Montgomery and Buffington 1993), shape and configuration of the stream network (Benda and others 2004), and soil and rock type. The four watersheds shown here illustrate the some of this variation. The North Fork of the Boise River (a) is outside the Plan area but is representative of parts of the dryer portions of the Plan area. In these steeper systems, periodic disturbances are relatively frequent because of wild fires but the disturbances have moderate impacts on the channel and the system is relatively resilient. Post- fire sedimentation can lead to large scale channel changes in small streams and locally in large channels at tributary confluences (Benda and others 2003b).

Lookout Creek (b) is on the westside of the Cascade Mountains. It is in an area of hard rock and has a relatively limited stream network. Additionally, the channel gradient is relatively steep. Wildfires and floods, the primary natural disturbances, are relatively infrequent but large. The

channel is generally resilient to disturbances, except at some lower gradients spots within the network. The range of conditions observed within the channel is relatively limited.

Knowles Creek (c) is in the soft rock Tyee sandstones of the central Oregon coast, similar to the streams studies by Reeves and others (1995). The primary natural disturbances are infrequent but large floods and wildfires. The watershed is characterized by relatively steep tributaries and a lower gradient main channel. The latter results in the deposition of large amounts of wood and sediment in the channel, which experiences a wide range of conditions over time as a result of disturbances events.

Redwood Creek (d) is in northern California. The basin is long and narrow and has a large natural sediment load. The upper portion of the basin is relatively narrow so material moves through it relatively quickly; as a result there is in-channel conditions are relatively stable. The lower end is lower gradient and a result is a depositional area. Consequently, there can be a wide variation in habitat conditions over time.



Chapter 10: Adaptive Management and Regional Monitoring

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Introduction

We have cast a broad net in evaluating adaptive management in the Northwest Forest Plan's (the Plan) first decade. We include the experiences with adaptive management areas, adaptive management outside of those areas, the regional interagency monitoring program, and some aspects of public-participation policy. Because the Plan tried an ambitious form of adaptive management, meeting all of its expectations would be an unparalleled achievement—this approach at this scale was never tried before the Plan. Adaptive management was seen as a cornerstone of the Plan, in response to clearly articulated uncertainties about how the chosen approach would play out. About 1.5 million acres (6 percent of the Plan area) were set aside into a land-use designation called adaptive management areas (see fig. 1-1), which were given a special mandate for learning. Regional monitoring grew out of directives specific to owls from the Dwyer injunction—and subsequent rulings—into specific requirements in the Plan (USDA and USDI 1994b). Although adaptive management and monitoring were implemented largely independently, we consider them together now because they are both central to the general process of adaptive management, also mandated by the Plan. We also evaluate how the concepts, presentation, and perhaps the goals of adaptive management continued to evolve during the Plan's first decade.

The Plan was designed to manage environmental risk by applying the precautionary principle, and to actively seek to reduce uncertainty with adaptive management and monitoring. The designers and implementers of the Plan recognized that uncertainty and risk are inherent in

Box 1

natural resource management and public policy (chapter 3). In social and ecological systems as large and complex as the Pacific Northwest, myriad interacting factors ensure that people's best-made plans or intentions are disrupted by unexpected human and natural events and, in retrospect, many rational predictions look more like guesses. Uncertainty arises in two major forms: natural variability of processes, and lack of knowledge. With variability, the process involved is understood, but the realized values can only be predicted within a range (for example, population growth rates or timber prices). In contrast, lack of knowledge includes both what is thought to be true (or false) but is not, and what is true but not thought about (such as unknown natural processes). When uncertainty intersects with objects or services of value, then loss can happen; the probability of lost value is known as risk.

The precautionary principle, as applied when the Plan was implemented, dictated that activities with risks of environmental degradation, such as harvest in riparian reserves or salvage, were halted or could proceed only if net ecological benefits of the action could be demonstrated. Thus, the Plan created a burden of proof that favored passive protective measures over active management. The Plan, as perhaps is not widely appreciated, also recognized the limits to this approach. Recognizing the benefits of active management in some instances, and the uncertainty in both action and inaction, Plan designers looked to adaptive management as a way to address uncertainty. The adaptive-management concepts of Holling (1978), Walters (1986), and Lee (1993) were added as the primary mechanism for using management activities as experiments, and thus having managers learn by doing. Through time, such learning would reduce uncertainty and be incorporated into Plan direction.

Conflict can arise when the precautionary principle is invoked without formal risk assessment.

With a consensus that possible negative outcomes are large relative to possible positive outcomes, little debate would happen regardless of different opinions or exact probabilities. For example, if a thunderstorm is approaching, few would question a decision to move children from a playground to a protected area. But many environmental decisions are not so obvious. Often the probabilities are not well understood, and assigning value to the range of possible outcomes is highly subjective. In disagreements among values, invoking the precautionary principle invariably favors one set of values over another. Similar conflicts can arise if different groups share the same values, but differ in assessing probabilities because of competing worldviews, or perhaps lack of trust. Formal risk assessment methods share the same shortcomings, but they have the advantage of explicitly revealing people's value judgments and probabilities.

Because the Plan language about adaptive management was somewhat vague and lacked performance standards, our assessment of intent is unavoidably subjective. Clearly, expectations were suggested in the Plan, and we use them where appropriate. We mainly use standards for an active form of adaptive management as described by Stankey and others (2003a):

- Applying elements of the scientific method (specifying hypotheses, highlighting uncertainties, and structuring actions to expose hypotheses to field tests);
- Collecting, processing, and evaluating results; and
- Adjusting subsequent actions in light of those results.

Evidence of Changed Direction

Evidence that these expectations were or were not met comes from the status and trends reports and various internal and external reviews, including an agency-funded review (Stankey and others 2003a). We later place the Plan experience in the broader context of how well adaptive management has been applied in other places. Because regional interagency monitoring is such an integral part of adaptive management, we look in detail at the regional monitoring program, and its dual role of measuring progress and advancing learning.

The primary goal of adaptive management under the Plan was to gain improved understanding to influence Plan changes through time. Clearly, the need for purposeful, systematic learning inside and outside adaptive management areas and in the monitoring program was envisioned.

Standards for determining when something has been learned were not developed, however. For example, how much time is needed to produce evidence of sufficient weight to alter the Plan was not discussed, nor does this question have a simple answer. How long depends on the nature of the issue, the inherent rates and dynamics of the processes, and the pace of learning. Much time and effort are needed to learn about complex forests, and perhaps 10 years is insufficient to form many concrete conclusions. Although some uncertainties might be resolved enough to allow quick changes in direction, others could require many decades. Another ambiguity was whether adaptive management was intended to evaluate the Plan approaches simply by monitoring them or to contrast them to alternative strategies, such as disturbance-ecology-based approaches, on the adaptive management areas.

Evidence of a well-coordinated, systematic approach to learning contributing directly to Plan changes is, so far, limited. Stankey and others (2003a) interviewed adaptive management area

participants who found the new approaches innovative, but candidly recognized the many barriers (internal and external, operational and systemic). An agency committee review⁷ found that managers in charge of adaptive management areas came to the same conclusion. They also reported that most studies were funded by the Pacific Northwest Research Station (about 30 studies; 4 that directly tested standards and guides and 7 that were in adaptive management areas). These areas were valuable in many ways, but they did not become a learning institution as envisioned by many of the people who proposed the idea.

Regional monitoring and various change mechanisms integral to the Plan do offer evidence of institutionalized learning and adapting. Local successes notwithstanding, evidence of a well-coordinated, systematic approach to adaptive management, including both adaptive management areas and monitoring, are harder to find.

Monitoring was well institutionalized—with multiple agencies working together—to measure Plan success and to provide new knowledge at a regional scale as a basis for decisions. Clearly, new knowledge was produced, and efforts (including this report) are underway to consider whether changes are needed. By itself, regional monitoring is a very passive form of adaptive management that does not compare alternative approaches and that is slower than more active forms of adaptive management (Bormann and others 1999). Evidence that a broad systematic approach was implemented in the Plan is also weak. For example, few links were made between regional monitoring and local monitoring or other adaptive management activities.

Several deliberate mechanisms of change in the Plan were successfully implemented. Required monitoring for murrelets in matrix lands led to half-mile-radius, late-successional reserves being created when murrelets were found. In response, the Siuslaw National Forest abandoned matrix management partly because they had previously found murrelets in about 90 percent of their surveys.⁸ The survey and manage species program was designed to deliberately change survey schedules and individual species categories and mitigation requirements, in response to new information; such changes were made (chapter 8). The NEPA-based decision in 2004 (USDA and USDI 2004b) to change from survey and manage to a sensitive species program, was based on several factors including cost. This change was viewed by some as passive adaptive management—a new approach was tried, evaluated, and then changed (whether the program was evaluated long enough is still debated). In contrast to changes induced by murrelet and other species surveys, evidence of adjustments in riparian buffers was uncommon (chapter 9).

The decision to thin plantations in late-successional reserves also provides some evidence that an adaptive management process was used. Various stand and landscape research and management studies and experiments—some sponsored by adaptive management areas or the Plan—presented initial evidence that thinning could speed developing late-successional characteristics in plantations in the late-successional reserves (chapter 6). These thinnings were not considered a major source of timber to meet timber production objectives in the Plan, and initially they were not included in the probable sale quantity. In the later years of the Plan's first decade, however, thinnings in late-successional reserves became a major source of timber, benefiting the economy of some local communities (Charnley and others, in press b), as well as appearing to move stands toward late-successional condition.

Other changes as the Plan was implemented were precipitated by courts, civil disobedience, or threats thereof, and some were precipitated to avoid contested projects. These types of unstructured reactions to immediate stimuli, appropriate or otherwise, are not widely viewed as adaptive management (Bormann and others 1999, Gunderson 1999a, Walters 1997).

Reflections on Adaptive Management

Any interpretation of adaptive management needs to consider ongoing processes that are producing understanding yet to be adopted (where the adaptive management loop is yet to close). Perhaps the most promising activity is the monitoring program and its 10-year interpretive report, to which this synthesis belongs. Here, we discuss problems and successes in the context of experiences with adaptive management outside of the Plan.

One difficulty in implementing and evaluating adaptive management is ambiguity in its definition. At one end of the spectrum are those that view any reaction to new stimuli as adaptive management. At the opposite end are those who invoke a more rigorous experimental framework characteristic of scientific research. Problems in the Plan seem to have started when no single definition of adaptive management was established. The Plan's most commonly implemented expression of adaptive management appears to be a very passive form, where a single approach was chosen (for example, on the reserves, with the preserve and protect tenets of conventional conservation biology), with regional monitoring as the primary feedback and learning mechanism. Most management experiments on adaptive management areas closely resembled

Box 2

traditional research experiments, with tightly constrained treatments on uniform small areas.

With a few exceptions, published concepts of active adaptive management (including the interagency implementation report, Bormann and others 1994) were not widely adopted (Pipkin 1998, Salwasser 2004, Stankey and others 2003a).

Implementing elements of a broader adaptive management strategy in the Plan area was piecemeal. Multiple interagency implementation teams, with both scientists and managers, were convened after the ROD, and released in five separate reports (adaptive management areas, adaptive management process (Bormann and others 1994), monitoring, information technology, and planning). Not surprisingly, implementation that followed was compartmentalized (for example, adaptive management areas in provinces, monitoring in the interagency monitoring program). Except for some of their local field personnel, regulatory agencies did not participate in designing learning activities, and many people concluded that their interpretation of adaptive management did not include activities that deviated from the standards and guides (Stankey and Shindler 1997, Stankey and others 2003a). An initial decision to allow adaptive management to develop without regional oversight was supported by scientists who argued against creating a cookbook for adaptive management (Bormann and others 1994). The limited direction, coordination, and motivational support from either regional or local decisionmakers, in retrospect, appeared to hinder adaptive management efforts. The perceived lack of progress slowed research and then management funding in adaptive management areas after 1998.

These results are fully consistent with experience in other places, where successful implementing of adaptive management remains rare (Walters 1997). Many of the obstacles that we observed

with the Plan are shared by other efforts. We see four main contributing factors:

First, perceived or real latitude to try different approaches on adaptive management areas was limited. Many of the FEMAT scientists thought that the areas would have wide latitude to test approaches that substantially differed from Plan approaches applied in the late-successional and riparian reserves. This need for experiments was clearly recognized as a way to respond to the large uncertainties in the Plan directions. The rules for adaptive management areas changed as the Plan was written, and most of the latitude was eliminated—for example, riparian reserve standards and guides were applied to all, and late-successional standards and guides to some, of the adaptive management areas, which took precedence over adaptive management standards and guides. After much debate, the Regional Ecosystem Office sent a letter clarifying the possibilities and needs for modifying standards and guides in the adaptive management areas (REO 2000). This letter created a mechanism to vary from standards and guides that was not widely adopted when other barriers appeared to come into play.

Second, some people saw adaptive management as a public participation process only. Specific collaborative goals were included in the Plan (in part because of the success of the pioneering community collaborative efforts in the Applegate Valley, Oregon), as a means for planning and accomplishing projects. Many of the adaptive management areas created new partnerships working through the new provincial advisory committees established by the Plan. The organized dialogue between managers of different agencies, regulators, and different constituencies improved communication and understanding between these players. Expectations of reaching consensus or implementing consensus ideas on the ground were not often met, however. Many of

the partnerships have lost momentum in the last few years (Stankey and others 2003a). Note that multiple efforts involving the public were undertaken outside of the adaptive management areas as well.

Third, precaution trumped adaptation. In contrast to the precautionary principle, adaptive management embraces risk and uncertainty as opportunities for building understanding that might ultimately reduce potential risks (Stankey and others 2003a). Withholding action until more is known is a rational response to uncertainty in many instances, but undue concerns with avoiding risk and uncertainty can suppress the experimental policies and actions needed to increase understanding. When minimizing the possibility of failure dominates policy and management processes, uncertainty is traded for a “spurious certitude” that provides a comforting, but illusionary, sense of predictability and control (Gunderson 1999a, Wildavsky 1988). Although the Plan’s precautionary strategy might be assumed to be the most viable approach to long-term protection of declining species, another perspective is to treat this assumption as a “question masquerading as an answer” (Gunderson 1999b).

Finally, regardless of good intentions, sufficient resources were not available to implement adaptive management as envisioned by FEMAT scientists or by the implementation team (Bormann and others 1994). Causes of inadequate funding are very complex. Various Plan requirements, such as watershed analyses and the survey and manage species program, consumed many of the available resources early on. Writing complex decision documents, continuing lawsuits, and regulatory consultations also consumed time of agency specialists. Decreased timber harvests reduced receipts that might have been used for monitoring projects on

adaptive management areas on FS lands. The most powerful evidence to consider is the decline in FS positions—a loss of more than 70 percent of the full-time employees on some Plan forests since 1990 (chapter 3). Reduced budgets made centralization attractive, and several forests and numerous ranger district offices were combined. Workforce motivation in this environment, especially to meet needs perceived as additional—like adaptive management—would be difficult for any organization. This context suggests that the agencies' decision to allocate substantial resources to the regional monitoring reflected a serious commitment to at least one aspect of adaptive management.

Examples of unfolding, potential successes of active adaptive management (as envisioned by researchers and some managers) can be found, despite all the problems. For example, the Blue River landscape management project, currently being implemented in the Central Cascades adaptive management area, helped develop a landscape prescription for matrix lands, based on a disturbance ecology approach, with deviations from standard and guides (Cissell and others 1999). The Five Rivers landscape experiment on the Siuslaw National Forest placed a 12,000-acre, replicated management experiment testing alternatives to growing late-successional habitat (Bormann and Kiester 2004). The Blue River study continued work that began on the HJ Andrews experimental forest before the Plan included the forest in an adaptive management area. After gridlock prevented implementing its predecessor in the North Coast adaptive management area, the Five Rivers project was applied outside the adaptive management area (Bormann and Kiester 2004). The Little Horse Peak project in the Goosenest adaptive management area was established to determine the extent to which different combinations of silvicultural treatments (especially tree harvesting and prescribed fire) can accelerate development of late-successional

forest attributes in mixed stands of ponderosa pine and white fir; the project is examining responses of many forest attributes, including vegetation, insects, and wildlife. These successes demonstrate that adaptive management can be possible outside of formal adaptive management areas if there is adequate management-agency leadership and research participation. As such they present models for future consideration.

Reflections on Regional Monitoring

Monitoring Observations

A framework for Plan monitoring (Mulder and others 1999) helped shape plans for monitoring a range of resources (Hemstrom and others 1998, Lint and others 1999, Madsen and others 1999, Reeves and others 2004). The interagency monitoring program coordinated all of these regional efforts and took charge of the 10-year interpretive report (5-year reports were mandated by the Plan), consisting of five status and trend (module) reports and this science synthesis. The monitoring program reported on trends in the Plan region over a decade or more in forest vegetation (older forests), implementation, and owl modules, and some aspects of socio-economics, and aquatic systems. In parts of other modules, the time series were much shorter; they are considered initial inventories or baselines for now. All monitoring modules have produced results that allow at least preliminary examination of underlying assumptions, conceptual models, analytical tools, development of descriptive or predictive models, and efficiency of protocols used in Plan monitoring.

We briefly express our interpretations of how well the regional monitoring program worked in its first decade. We then present an adaptive-management-oriented conceptual model for monitoring, as a way to look forward to improving monitoring in support of future interpretive reports (the Plan called for 5-year reports). A thorough assessment of the monitoring program is beyond the scope of this chapter, but such an assessment would provide substantial useful information for future decisions. Our retrospective interpretations are:

- Monitoring was the activity making greatest progress in meeting the regional expectations of adaptive management established in the Plan. Monitoring took the first step in moving from opinion toward evidence-based decisions (opinion will always be involved). Monitoring provided the opportunity for using feedback to make midcourse corrections. Adaptive management can't be done without monitoring; monitoring without adaptive management is just data.
- The Plan helped institutionalize adaptive management at regional scale through the monitoring program and 10-year interpretive report. This report brought strong focus on what has been learned, improved communication, and raised the chances that knowledge will be incorporated in future planning, implementing, and monitoring, which meet the criteria of McLain and Lee (1996).
- Plan monitoring provided our first estimates of measurement error and underlying variance of key Plan indicators. Sampling strategies can be evaluated for the first time, and fine-tuned to become more efficient, now that we have an understanding of this variability. Such data are valuable even where significant trends have yet to be observed.

- The regional monitoring program demonstrated the agency's ability to work together effectively.
- Monitoring was expensive—about \$50 million over 12 years (about 17¢ per acre per year). Most resources were focused on continuing owl demographic monitoring (about \$25 million).
- The compartmentalizing of monitoring into implementation, effectiveness, and validation monitoring—and then a dominating focus on effectiveness—probably limited learning. Because people believed being “effective” was more important than creating records of activities that could be assembled for regional analysis or more important than questioning the many assumptions, effectiveness was monitored while record-keeping and skepticism waned. Two legs of the monitoring stool were quite weak (implementation monitoring and research efforts notwithstanding).

Monitoring Concepts

We propose a conceptual model for monitoring consistent with evolving ideas about adaptive management, with some minor changes in emphasis from Mulder and others (1999). The most important premise of this model is that the monitoring questions reflect crucial management decisions. The primary purpose of monitoring is to inform future decisions and meet legal obligations, not to do research or public relations. Once the questions are chosen, then the emphasis is on applying the best available technical approaches for data collection and compilation. When technical issues are addressed rigorously, most large-scale ecosystem monitoring will be expensive. Thus, we propose that the ideal set of monitoring questions will

- Be chosen by accountable decisionmakers (with input from others);
- Be focused on a limited range of possible future decisions;
- Be as durable as possible, so results are still useful when they are finally produced;
- Have quantified expectations laid out in advance, so monitored deviations from expected outcomes can serve to make clear conclusions about changes;
- Reflect a broad spectrum of public opinion; and
- Be linked to potential management changes by laying out in advance explicit assumptions and potential management responses.

The monitoring results complete an adaptive management cycle when they influence management decisions. Formal methods for linking decisions to monitoring can facilitate this process. A monitoring program is a proactive strategy for managers to inform and counter external forces driving policy shifts with more internal knowledge. Other, less tangible benefits from monitoring could be considered as well, such as building public trust, cross-checking assumptions, learning about emerging questions, and institutionalizing adaptive management.

Box 3

Our monitoring model has technical aspects to consider, such as: Do chosen variables answer the question posed?; Is monitoring efficient?; Is monitoring information effectively summarized and communicated? These questions are addressed briefly before preliminary recommendations are presented.

Do Chosen Variables Answer the Question Posed?

Fundamental to monitoring a large, complex ecosystem is choosing the variables or metrics most appropriate to the questions posed and their scale. Because of spatial and temporal complexity, simply choosing what to measure is not enough; when and where are also important. The Plan embodies conservation goals and implementation standards across 22 million acres of federal land in the Northwest. At the finest resolution, the Plan is implemented with management decisions affecting as little as a few acres or restricted stream segments. The challenge is how to most effectively meet information needs at multiple scales. Ideally, aggregating monitoring information up from local scales would help higher in the hierarchy, and monitoring at large scales would provide valuable context for more localized questions (Busch and Trexler 2003, Morrison and Marcot 1995). Choosing where to measure requires understanding the primary scales of interest to decisionmakers and how there are inferences among scales. Clarity about the acceptability of developing stronger inferences where data and analyses can be aggregated to a regional scale, together with acceptance of weaker inferences at smaller scales, would be helpful. Initial monitoring results showed how information on nonfederal lands can serve a more complete ecosystem analysis, which has so far been accomplished only with inventory and remote-sensing data. Because potential responses may play out quickly or slowly, determining if the intensity of data collection can detect projected trends is also important. Monitoring some variables on a nearly continuous basis and others less frequently may also be reasonable.

Is Monitoring Efficient?

The efficiency of monitoring under the conceptual model we use lies with how useful the results were per unit of monitoring effort. Measuring this kind of efficiency is complicated by the time lags between collecting data and considering findings in decisions, and by the various intangibles of decisionmaking. Most effort is therefore usually focused on other forms of efficiency. Several mechanisms were incorporated into the Plan's monitoring program design, with the prospect of making the program operate efficiently, and to become more efficient over time (Mulder and others 1999). Many of the efficiency issues address aspects of the sampling designs.

One tradeoff is between using statistically rigorous sample design compared to scientific consensus. Both were used, and reasons may be found to adjust monitoring program elements toward one approach or the other. Another tradeoff lies between sampling and spatial resolution. For example, by randomly selecting study sites, inferences drawn from the data monitored in the watershed-module applied to the entire Plan region—at the cost of limited spatial and temporal resolution. Risks and benefits of such approaches in all monitoring modules are reasonably well known, so a determination about the desired course for the program as a whole (either change or continuity) should be possible.

Another issue is whether new information about dynamic ecosystems has been incorporated into monitoring design, and if the information needed about disturbance is at odds with monitoring of the Plan's land-use designations. Monitoring programs have not been oriented toward detecting the effects of environmental disturbance or how dynamic environments interact with land-use designations. Despite their focus, some sampling designs may be able to detect change caused by disturbance. Monitoring based on interpreted satellite imagery with complete coverage or based

on probabilistic sampling approaches are best suited to conducting analyses on disturbances detected by the monitoring protocols. Sample-size limitations can, however, constrain inferences about types of disturbance at multiple scales (for example, effects of slope failure in key and non-key watersheds or effects of fire in late-successional reserves versus matrix).

The relative value of monitoring wildlife populations or their habitat is also important. The Plan stressed the role of the FS and BLM in managing habitat to provide for viable populations of desired species. Monitoring plans adopted a strategy where habitat models would complement or partially replace some direct monitoring of populations. In addition, watershed monitoring included a strategy where watershed models would obviate the need for extensive instream measurements. The hope was to gain efficiency by using robust databases on both habitat and populations, and by developing models for projecting populations based on habitat condition. At this point, the proportion of the variation in owl population vital rates that can be explained by habitat variables is too small to make reliable predictions about demographic characteristics and, thus, population trends. Some indications suggest that monitoring vegetation may be more reliable in predicting owl and murrelet presence than populations. Although some differences in watershed condition were apparent across different Plan land-use designations, whether subtle trends in condition will be discernable over time is unclear. Even less certain is that watershed condition will have much predictive value in describing instream factors or aquatic populations. Although better data and better models are unlikely to ever permit complete conversion to habitat-based monitoring, strategic development of models is an important research tool with potential for helping to make predictions and develop cause and effect relations.

Another key issue is continuity in the face of changing technology. Recognizing the value of continuity when considering changes to the monitoring program is important. Variables with a longer record or a record that can be retrospectively assessed may be more useful than those of short duration, all else being equal. Changing course in midstream can come at a high price.

Wall-to-wall remote sensing approaches, however, used in the first decade may be at a point for change. The Thematic Mapper satellite is failing. We suggest that some form of three-dimensional measures of forest structure (LIDAR, IFSAR) linked with digital aerial photography will present the most value for the next decade. This approach can produce positional (x, y, z) data that do not require additional interpretation, at a scale of individual trees.

To ensure long-term success of the Plan, increased emphasis on monitoring that can improve understanding of cause and effects is important. Agency and university researchers attempted to analyze some of the Plan's underlying assumptions, but the process was largely ad hoc. Some cause and effect links are possible at regional scales; for example, the stand-replacing disturbance can be compared to management history. Many links are not possible; for example, smaller disturbances cannot be detected with current remote sensing. Confounding factors will always limit cause-effect links; the only way to reduce confounding is through more structured learning (rigorous comparisons in designed management experiments). Few midscale management experiments envisioned for adaptive management areas were designed or implemented (with some notable exceptions). These efforts could be considered part of a system of adaptive management and monitoring in the next decade.

Is Monitoring Information Effectively Summarized and Communicated?

We discussed how change in management direction could be used as evidence of adaptive management in play. Change in management direction could also be used as evidence of how effectively monitoring information is summarized and communicated. To be fair, judging success or failure now is too early—the status and trend reports and our own synthesis were just released. Nonetheless, we think some opportunities to improve how monitoring is summarized and communicated are available.

Models can help to summarize and characterize understanding, but they are only as good as the data and assumptions they use. Models can help identify and estimate causal relations, quantify strength of evidence for alternative hypotheses, and be used to make (or update) projections for objects of interest. New information accumulated since Plan inception might provide a basis for adjusting models underlying the regional monitoring program. Clearly, some influential factors were less understood before, such as potential barred owl effects on spotted owl populations.

Other factors may affect all systems monitored, but they may be thought of as exerting their influences less directly, such as global climate change or forest-marine ecosystem links.

Increasing social awareness of issues such as fire and invasive species and activities by managers to address these questions also argue for potential model revisions. The models developed for effectiveness monitoring have helped to develop and implement the modules. Given the above, incorporation of “new” factors in revised models could be considered before changing monitoring protocols. Without this step, discussions of prospective change might not provide sufficient rationale for change, or could be viewed as unjustifiably producing winners and losers in terms of the subsystems monitored.

Lastly, the monitoring program sometimes suffers from a lack of clearly articulated expectations or goals. Information now exists to rectify this shortcoming. For example, the monitoring program has yielded important information on the amount and distribution of old forests under various definitions, on the distribution and abundance of marbled murrelets, on demographic parameters for owls, on watershed condition, and on social and economic conditions throughout the Plan area. Data can now help clarify baselines and targets with greater accuracy than was possible at the beginning of the Plan. Because targets are based on social values and agency policies, decisionmakers need to help articulate them.

The Costs and Benefits of Regional Monitoring

We consider the value of what was a unique experience with regional-scale, interagency monitoring linked directly with land management. The costs of regional monitoring under the Plan were substantial (table 10-1 by agency; table 10-2 by monitoring modules). Although the total amount (\$50 million) is large, the per-acre cost for 12 years was about \$2 per acre, or less than 17¢ per-acre per year. For the last four years, costs have averaged about \$6 million per year. The costs are not shared equally across the various modules, however; owl monitoring accounts for half of the total costs. Watershed conditions and marbled murrelet monitoring were the next two most costly. Before fiscal year 1999, these costs are underestimated because contributed staff time spent developing monitoring protocols was not accounted for. At the Pacific Northwest Research Station in the early parts of the decade (1994 to 1998), support for the developing monitoring protocols and initial monitoring was two to three times what is shown in table 10-2 (see appendix 5 in Haynes and Perez 2001). After monitoring began in earnest, this support was reduced as efforts shifted from research to the monitoring program.

To put the costs in perspective, regional monitoring was about 12 percent of the cost of implementing the Plan and about half of what was spent on the survey and manage species program when it was at its peak. Regional monitoring may have also reduced the costs of local monitoring. The costs are offset by many benefits, especially when monitoring is seen as a vital cog in an adaptive management strategy. Monitoring can not be judged in isolation but by how well its interpretation integrated knowledge from available sources and facilitated decisions on whether course corrections are needed. Although room for improvement clearly exists, we conclude that regional monitoring and its interpretation:

- Complied with specific legal mandates;
- Provided information about progress at a regional scale to help identify when changes should be considered, thereby completing a loop in the adaptive management cycle;
- Provided a venue where managers and researchers can consider recent research findings holistically and in the context of the complex societal and legal environment;
- Began to substitute opinion with data-based evidence, where possible;
- Institutionalized part of an adaptive management system, and—perhaps more important—convinced managers that adaptive management is an integral part of management; and
- Provided an opportunity for increased trust between agencies and among constituents by better communicating progress towards achieving broad goals.

Considerations for Future Progress in Adaptive Management and Regional

Monitoring

We present some initial ideas to improve the regional monitoring program, as we were asked to do by the regional agency executives. Because regional monitoring is only part of a systematic approach to adaptive management, we then offer ideas on ways to improve adaptive management more generally.

Improving the Monitoring Program's Second Decade

Ways to improve the monitoring program:

- Consider committing to interpreting regional monitoring and research every 10 years, if not more often to gain the most value from the monitoring effort.
- Consider developing a list of corporate questions to set up the next interpretive report and defining priorities in this list based on decisionmakers' understanding of emerging issues, their vision of future societal goals, and the cost and feasibility of obtaining quality monitoring data.
- Consider developing a new adaptive-management-oriented monitoring framework that includes new monitoring plans with quantitative expectations from experts and others and potential management responses to deviations from expectations (without clear expectations, clear changes cannot be measured or interpreted).
- Consider focusing more effort on agency record keeping, vital to any future interpretive analysis. Our team was not able to assemble existing local activities records, such as thinning and prescribed fire, into a regional analyses, in part because no mechanism to do so existed.

We have also seen evidence that previous FS record-keeping systems have been replaced with ad hoc local record keeping.

- Consider ways to overcome obstacles to coordinating monitoring at different scales and from different sources, including projects, management experiments, assessments, inventory, and other federal and state agencies (Busch and Trexler 2003, Morrison and Marcot 1995).
- Consider reallocating some resources to testing assumptions and learning about mechanisms that explain management effects or population trends, in management experiments and mechanism-oriented research; also considering supporting retrospective monitoring by using old agency records.
- Consider promoting multiple methods of quantitatively interpreting monitoring data. Using traditional Neyman-Pearson statistics, Bayesian statistics, and exploratory data analysis helps to strengthen evidence.
- Consider continuing to make data and interpretations widely available.

Changing the Course of Adaptive Management

Whenever scientists and managers get together to discuss large-scale resource management issues, two common refrains are heard. Managers complain that risk-averse policies and regulations limit their ability to manage effectively. Scientists complain insufficient attention is paid to uncertainty, monitoring is underfunded, and rigorous learning from management experience is not valued by risk-averse decisionmakers. Unfortunately, considerable truth lies in both complaints, yet neither perspective is entirely accurate or easily addressed. The precautionary principle is clearly in play in the Plan, and the burden of proof required of

managers before they act is perceived as very high, but some avenues for action are clearly permitted in the Plan. Similarly, regional agency executives have made major investments in monitoring and evaluating the Plan's success—for example, this report is a result of the agencies' commitment to a periodic evaluation of what has been learned as a basis for possible change in direction. The path to reduced uncertainty and manageable risk, however, is not the exclusive purview of regional executives, analysts, or science teams.

We suggest several potential adjustments that might further the broad aims of adaptive management, which ultimately is to improve management to meet societal needs. These suggestions augment the various observations made throughout this report. The experience in the Plan's first decade suggests that the effectiveness of adaptive management can be increased by bringing together the wide array of learning and adapting activities into a more coordinated, directed, and institutionalized system designed to be more than the sum of its parts. Many elements started in the first Plan decade need only to be better coordinated in an adaptive system (fig. 10-1). Developing this system will likely require staff work, key decisions, and continual support and nurturing by managers, regulators, and researchers.

Box 4

Implementing management experiments—

One of the most important, least developed elements of a systematic approach to adaptive management (fig. 10-1) is management experiments (on or off the adaptive management areas). Active adaptive management compares alternate management pathways in management experiments applied, not as research projects, but as well-designed, agency-led administrative

studies undertaken as an integral part of management itself. These experiments, conducted on or off adaptive management areas at the normal scale of management, would include alternative strategies or “pathways” to achieve specified goals of the Plan. Management experiments are extensive in that they will not require intensive monitoring as typically required in research experiments; monitoring will be more in line with project monitoring (such as stand exams, surveys, photo interpretation, and remote sensing). Management experiments offer an opportunity to provide increased understanding of the actual effects caused by management, not possible with regional monitoring or even by limited-scale, limited-scope research projects. What can be learned comparing practical approaches in these trials strongly complements status and trends emerging in regional monitoring and understanding of new mechanisms in research. Comparing alternative pathways also meets the adaptive-management intent of the Plan, to accelerate learning while managing as a way to respond to the high uncertainties associated with implementing approaches never tried before.

Large-scale experiments may be viewed by some people as risky or in violation of the precautionary principle. Management experiments often make more sense at a scale large enough to reflect the complexity of the landscape and the management strategy. Aggressive learning comes from management actions that challenge underlying assumptions and provide sufficient strength of evidence in a timely manner to distinguish between competing hypotheses. Where management experiments need to include treatments that exceed regional standards and guides to provide enough contrast, regulatory and court actions may be needed for this flexibility. Not all management experiments need to violate standards and guides; they simply contrast alternative approaches to achieving an objective, as in the Siuslaw National Forest’s Five Rivers project.

The challenges are clear.

Other important ways to learn—

Not all learning will be gained through monitoring or management experiments. Other important opportunities to gain information may lead to management changes as well. First are the opportunities to exploit retrospective observations. The forests we manage today are a legacy of past actions. What can we observe from the various actions and the associated trajectories that forests have followed over the last 50 years with agency records and aerial photography? Second, we could try to explore the considerable knowledge and experience of active management gained on private timberlands. Other insights from indigenous and local communities may also spark important creative leaps in both questions and approaches. Changing the cultures of federal, industry, private land managers, and also researchers to equally value this observed or existing knowledge will be a challenge.

Obstacles to learning are not easily overcome, as the experience in the Plan thus far attests. We offer the following principles for effective adaptive management and monitoring:

- **Engage multiagency regional executives in guiding learning.** Agency executives and their staffs bring a perspective and authority that is essential to defining the most important questions to be answered in the next decades and to managing regional experimentation and monitoring. Engagement also increases the chance that what is learned will be incorporated in future decisions.
- **Involve regulatory agencies.** Collaboration with regulatory agencies is especially important

in facilitating and learning from more controversial management experiments. For example, if management experiments are properly structured and explained, they can be seen as a way to improve environmental conditions or sensitive species' habitat, not as risks to them.

- **Accommodate reasonable disagreements.** Where uncertainty is high and competing social values and constituencies are connected to different bodies of knowledge and experience, consensus on a single management strategy may be an unreasonable goal. Disagreement can be used to develop different strategies for testing, and it can even help to connect back to multiple constituents.
- **Commit to quality record keeping.** A regionally compatible system with a quality matching the current BLM or the old FS total resource inventory (TRI) system would document land management activities so they can be compiled across the entire region. Securing, properly archiving, and making accessible old records are also vital to learning. Many of these records are disintegrating, and some have been lost. Retrospective studies of long-term processes require these records.
- **Recognize and address local knowledge needs.** Spatial and temporal complexities in the Pacific Northwest region, in subregional landscapes, and even in smaller areas dictate that local evidence and knowledge are important to land management decisions. Local experts and the public are best positioned to identify information needs, and help design site-specific, midscale management experiments to address them. Engaging and supporting community research efforts have the added benefit of building broad-based support for a regional adaptive management program.
- **Organize around a regional monitoring program.** The regional monitoring program has

reduced uncertainty and helped agencies apply adaptive management. Other adaptive management activities, such as midscale monitoring and regional and local management experiments, could be coordinated through the regional monitoring program. Linking regional monitoring to record keeping, monitoring at other scales, or by other agencies and research will remain a difficult proposition, requiring significant attention.

- **Build institutional capacity through employee training.** The complexity of planning adaptive management linked to both local and regional monitoring, designing and implementing management experiments, and interpreting monitoring results would likely demand a significant investment in training that crosses scales and agency boundaries. A new within-agency certification system (perhaps building on the silviculture institute concept) might be considered. Boundary spanning assignments might become part of such a system, where field specialists and researchers would work together on relevant research and management experiments.
- **Value continuing partnerships between researchers and managers.** A sustained partnership (more than periodic regional assessments or evaluations) would aid in overcoming traditional barriers between researchers and managers. Learning from management in a scientifically credible way may meet resource objectives and advance science at the same time. In one approach, pioneered at Five Rivers, researchers provided advice on designing management experiments and rigorous monitoring techniques and helped with interpretation of data, managers provided leadership and implemented landscape experiments and monitoring, and researchers are seeking to provide knowledge to peer-reviewed literature from retrospective research on learning from past management and disturbance (Bormann and Kiester 2004).

- **Develop long-term funding strategies.** Funding will likely remain a major limiting factor for learning (Stankey and others 2003a). A rate of investment in learning commensurate with the value of the information obtained is easily justified, but long-term benefits will have to compete against problems of the day. Regional management-agency staff could learn how to better justify adaptive management expenses to their national offices where funding allocations between regions are made. An alternative approach would be to invest a fixed percentage of incoming receipts (from timber sales, recreation passes, and other sources) in increasing the quality of managing the forest. The Coquille Forest Plan proposed a fixed allocation of 15 percent of timber receipts for monitoring. Some constituents have argued that when agencies are allowed to use timber receipts, an incentive is set to perpetually increase timber harvest and benefits to corporations. Such challenges can be countered only by describing the long-term benefits of learning to society and to the forest itself.
- **Reshape the burden of proof and the precautionary principle.** Managers, regulators, and others are not “embracing uncertainty” (Lee 1993) when they place a heavy burden of proof on those who either wish to protect nontimber resources (as in the past) or on those who wish to actively manage forests (as the Plan was implemented). With uncertainties of the magnitude we see, and because chosen approaches have never been tried before, demonstrating proof of either kind is not possible or reasonable. We have also learned in the past decade that doing nothing—by applying the precautionary principle as a regional standard or legal directive—is a choice that has much uncertainty as well, and some potential for highly undesirable outcomes. A different set of burdens could be articulated (whether some constituencies and courts can be convinced remains to be seen).
- **Diversify practices.** Uncertainty leads us to try multiple approaches to meet a goal so that all

of our eggs are not in one basket. We also could benefit from learning how to effectively hedge our bets (chapter 3).

- **Structure learning.** Uncertainty about management outcomes can be reduced through formal methods of learning, applied most effectively—not as small-scale research studies—but as management itself (in representative areas).
- **Maintain critical mass.** Enough technical expertise (across multiple disciplines) is needed locally to understand local limits to general knowledge and apply complex multiscale management scenarios.
- **Promote social tolerance.** Perhaps, the most important method to embrace uncertainty is to create more pluralistic, multiconstituency agencies by simultaneously applying approaches promoted by different constituencies—so that each constituency can see their ideas reflected in at least part of the landscape.

Finally, the Plan's institutionalization of an interpretive report is an important success that could be continued and considered in the design of other monitoring programs. The report is important because it brings a periodic focus on what was learned, improves communication of what was learned, improves integration of science disciplines and science and management, and raises the chances that knowledge will be incorporated in future planning, implementing, and monitoring. Here is where the agencies have a good chance to meet the criteria of McLain and Lee (1996): producing new understanding, incorporating that knowledge into subsequent actions, and creating venues in which understanding can be communicated.

Table 10-1—Plan monitoring expenditures by agency^a by fiscal year (Oct. 1)

Agency	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
<i>Thousand dollars</i>													
BLM	549	549	636	625	318	1,272	889	1,313	1,249	1,306	1,294	1,218	11,218
R5	193	193	234	234	209	354	322	774	839	885	995	973	6,205
R6	549	549	635	625	494	1,631	1,332	2,050	2,212	2,326	2,263	2,425	17,091
NPS					68	105	140	190	190	140	140	115	1,088
FWS			20		20	724	481	396	411	416	435	435	3,338
PNW	549	549	549	508	415	876	476	602	630	452	520	607	6,733
PSW						90	270	179	200	200	135	135	1,209
USGS					302	365	234	234	231	226	185	67	1,844
EPA						60	103	90	90	90	120	110	663
NOA-F						45	0	100	170	170	170	90	745
Total	1,840	1,840	2,074	1,992	1,826	5,522	4,247	5,928	6,222	6,211	6,257	6,175	50,134

^a Contributing agencies

BLM – OR/WA Bureau of Land Management
R5 – USDA FS, Pacific Southwest Region
R6 – USDA FS, Pacific Northwest Region
NPS – National Park Service
FWS – US Fish & Wildlife Service Western Region

PNW – USDA FS, Pacific Northwest Research Station
PSW – USDA FS, Pacific Southwest Research Station
USGS – US Geological Survey
EPA – Environmental Protection Agency
NOA-F – National Oceanic & Atmospheric Administration –
Marine Fisheries

Table 10-2—Plan monitoring expenditures by monitoring module

Module	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
	<i>-----Thousand dollars-----</i>												
Spotted owl	1,840	1,840	1,840	1,740	1,626	2,291	2,117	2,363	2,553	2,369	2,548	2,612	25,774
Marbled murrelet						1,490	854	1,139	987	767	814	738	6,789
Older forests						752	446	411	486	777	551	433	3,856
Watersheds						422	450	1,426	1,053	1,007	1,252	1,223	6,833
Implementation			234	252	200	250	200	239	263	280	225	216	2,359
Socioeconomics						17	25	140	200	383	400	395	1,560
Biodiversity						75	75	35	58	47	47	27	364
Tribal								10	40	58	105	76	289
Program management						225	80	165	582	523	315	455	2,345
Total	1,840	1,840	2,074	1,992	1,826	5,522	4,247	5,928	6,222	6,211	6,257	6,175	50,134

Figure List

Figure 10-1—A more systematic approach to Plan-wide adaptive management. Corporate questions drive various learning activities that feed into interpretive steps facilitating decisions on whether course changes are needed, as well as on whether to revise the questions. Design and balance among these elements are needed to gain the most from this system.

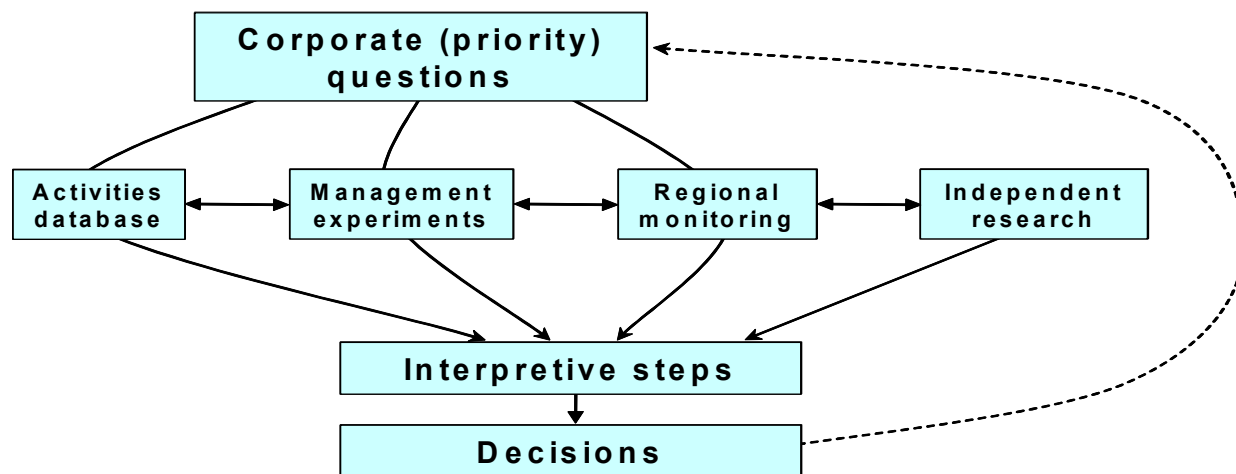


Figure 10-1.

Box 1

The Precautionary Principle

The precautionary principle has become increasingly prominent in environmental management. Simply stated, it rejects inaction as a response to uncertainty. A widely quoted definition from the 1992 Rio Declaration[§], states:

In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

The basic idea behind the precautionary principle is common to human experience; where a possible but uncertain threat to life or property exists, precaution calls for reasonable effort at avoidance. Sometimes avoidance calls for active measures (such as, security screening in public buildings), and, at other times, stopping activities that might otherwise take place (such as, prohibiting use of cell phones on airplanes).

Note that the precautionary principle does not advocate avoiding all actions with possible negative consequences, nor does it suggest avoiding environmental degradation at all cost. As defined in the Rio Declaration, the precautionary principle is fully consistent with formal methods of risk assessment and risk management that have been developed as models of rational behavior. In quantitative risk assessments, a range of plausible outcomes is identified and probabilities are associated with each outcome. Expected loss, or risk, is calculated by summing the probability of each outcome multiplied by its associated loss or gain in value. Decisions that result in high expected loss are viewed as undesirable. The precautionary principle logically follows when negative outcomes are highly probable, or when the magnitude of the potential loss is very high relative to possible gains, regardless of probabilities. In either case, attempting to reduce the chance of loss is prudent.

[§]Drafted at the 1992 United Nations Conference on Environment and Development, also known as Agenda 21.

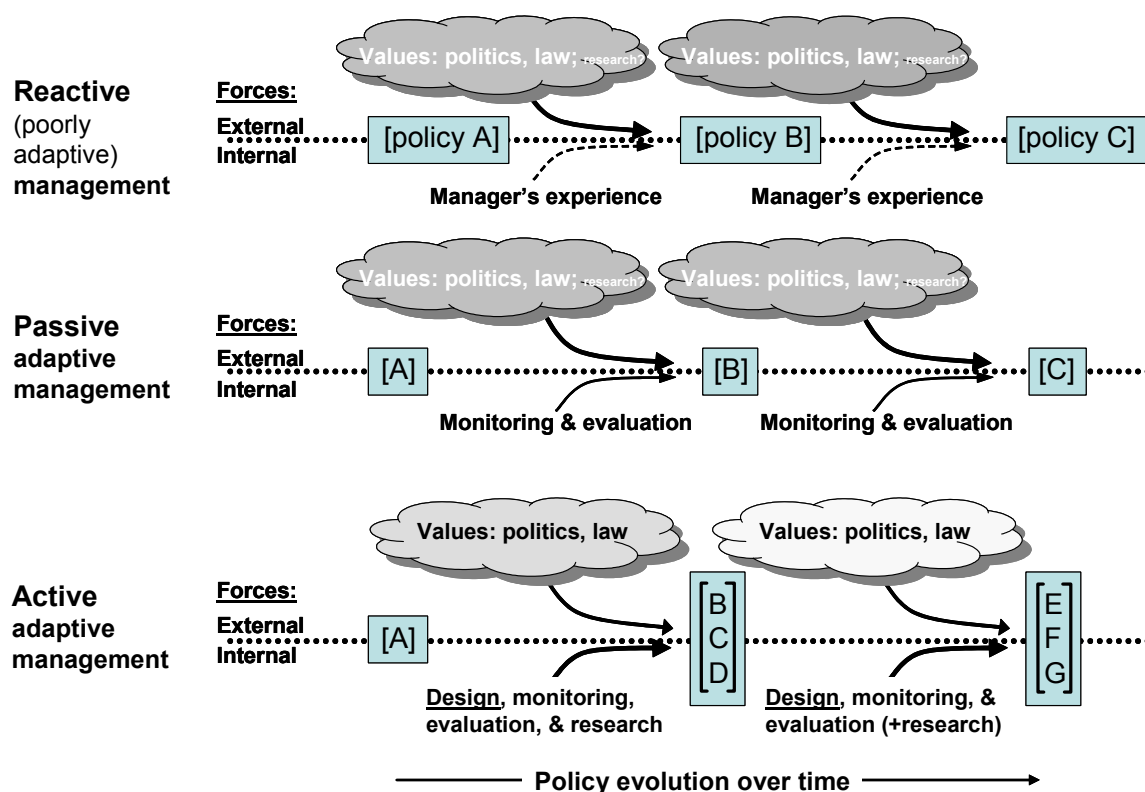
Box 2

Forms of Adaptive Management

The literature describes three main forms of adaptive management: reactive, passive, and active (figure below). The forms differ in the degree that external factors (such as legislators, courts, and civil disobedience) drive policy evolution more than learning activities internal to the management system and in how fast policies can evolve given the lengthy evaluation period needed.

- **Reactive management** is not thought to be very adaptive when policies change A to B to C without much influence from what was learned on the ground.
- **Passive adaptive management** adds a specific monitoring and evaluation step to increase the influence of internal knowledge, potentially improving the subsequent policy but perhaps with little effect on the rate of policy evolution.
- **Active adaptive management** adds a design step, seeking to speed policy evolution and make research more of an internal force. Designed “management experiments” speed learning by trying a set of policies simultaneously with scientifically defensible experimental designs (usually subject to rigorous peer review).

Learning is a function of the strength of monitored comparisons; comparing multiple policies simultaneously with replication is far more powerful than trying one at a time. Active adaptive management should not be confused with research—although employing an experimental design, management experiments are developed, implemented, and monitored by managers, with only consultative help from researchers.



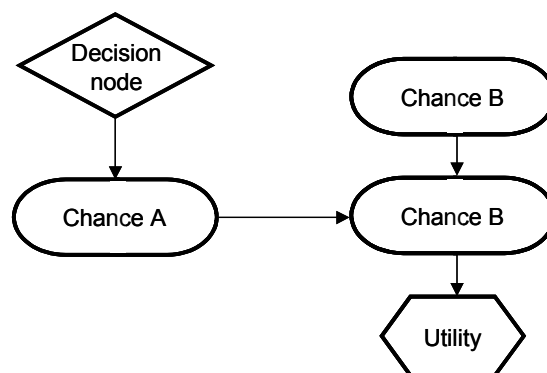
Use color

Box 3**Decision Models**

Decision models take various forms. One framework for linking decisions to monitoring (see Lee and Bradshaw, in prep) involves the use of influence diagrams (Clemen 1996, Howard and Matheson 1981). An influence diagram is intended to represent the decision process in a way that explicitly recognizes the uncertainty in consequences or outcomes of the decision. Influence diagrams consist of nodes or variables connected by directed arrows (below). Three kinds of nodes exist: decision nodes represent alternative actions that might be taken; chance nodes represent events or variables affected by the decision or other chance variables; and value or utility nodes representing variables summarizing the final outcome of a decision. In business decisions, value nodes are often expressed in monetary units. For other kinds of outcomes, the relative benefit offered by a particular outcome is summarized by its utility, a non-dimensional metric that allow comparing dissimilar elements (such as, fish versus timber). Relations between outcomes and utility are expressed as utility or preference functions; such functions reflect both comparative value and attitudes about risk (Keeney and Raiffa 1976). Although decisions can be analyzed without explicitly assigning values or utilities to outcomes, the act of choosing one outcome or the other as preferable implicitly reveals a preference function.

An influence diagram is more than simply a schematic representation of the interaction of decisions and chance variables. Well-established statistical methods are used to quantify the strength of causal dependencies by using conditional probability matrices that link chance nodes to decisions or to other chance nodes. Influences are propagated mathematically through the network such that conditional changes in probability at each node are calculated based on the decision option and various input variables. The mathematical framework underlying influence diagrams provides a strong conceptual link to statistics, and a rigorous means of using experimental results or monitoring data to update or verify the diagrams.

Influence diagrams are commonly used to identify the decision option with the highest expected utility given the information in hand, but they have other uses. One purpose they serve is to allow calculating the value of information. That is, they rigorously calculate the change in expected utility given a reduction in uncertainty about a particular chance node. Many businesses use this type of analysis to decide whether investing in additional information gathering or research before making a decision is cost effective. Sensitivity analyses are also easily accommodated, in which the variables most critical to making an optimal decision are identified.



Decision model: a simple influence diagram with one decision node, three chance nodes, and one utility node. Arrows indicate causal dependencies or effects; that is, the decision has a direct influence on chance node A, chance node A and B affects C, and utility is derived from C.

A More Systematic Approach to Adaptive Management

Box 4

Key system elements—many of these elements were started in the first Plan decade and need only to be coordinated in a systematic approach (see fig. 3-3):

- **A periodic, institutionalized interpretive step.** This step is needed to integrate and synthesize disparate information from monitoring and other sources over a sufficient period so that decisionmakers can more fully understand the context for truly adaptive course adjustments. In the Plan, 10 years of monitoring and research worked well to fuel the 10-year interpretive step. More frequent interpretive workshops may prove useful as well.
- **A prioritized list of corporate questions and learning objectives.** Because of time lags in monitoring, research, and evaluation, defining questions now for the next interpretation step is critical. Corporate questions are needed to drive multi-agency regional monitoring, and subregional learning objectives are needed to direct management experiments.
- **Linkage and balance among corporate learning activities.** Activities need to be linked through the questions and learning objectives. Resources from management and regulatory agencies need to be balanced among the three main activities:
 - **Agency record keeping** clearly describing what management happened, that can be assembled for regional analysis in the next interpretive step (including old records).
 - **Regional monitoring** focused on documenting outcomes for a diverse subset of key outputs and conditions (avoiding indicators, if possible), and also yielding information on unexpected changes and uncertainty, and taking advantage of monitoring by others. Publishing quantitative expectations is also essential to interpreting subsequent outcomes.
 - **Management experiments** (on or off adaptive management areas) designed to produce evidence of links between management direction and changes in outputs and conditions, and to evaluate alternative pathways (preferably linked to different constituents).
- **Research explicitly linked to this system.** Research explicitly linked to questions and learning objectives is also an important learning activity (note, unlinked research is also important because it may produce unexpected results of considerable importance and relevance to future decisions). Researchers are well suited to:
 - Help **frame questions, design monitoring, and design management experiments** to guide learning for the next interpretive step;
 - Lead periodic **interpretive steps** to synthesize and integrate available evidence from monitoring and research in a broader, longer-term framework;
 - Conduct **retrospective studies** of past management to uncover temporal uncertainties and causes and effects of past management, as a basis for looking forward; and
 - Conduct **research experiments** that can address more-focused elements of the corporate questions, or to evaluate effects of specific practices.
- **Upward links.** Links are needed to the planning regulations, the environmental management system, and to the national budget-allocation debate (learning is a legitimate agency output).

A financial and institutional commitment to producing evidence of sufficient weight and relevance to counterbalance some of the external forces driving policy change. Consider a fixed percentage of total financial resources (perhaps 15 percent) and developing more administrative processes to make learning and adapting core business (including training, rewarding, and so on).

Footnotes

¹ G. Olson, 2005. Personal communication. Assistant professor, Department of Fisheries and Wildlife, 104 Nash Hall, Oregon State University, Corvallis, OR 97331.

² These zones are defined in the marbled Murrelet recovery plan (USDI 1997): Conservation Zone 1 is Puget Sound and Strait of Juan de Fuca in Washington; Zone 2 is the outer coast of Washington to the Columbia River; Zone 3 is Oregon south from the Columbia to North Bend, Zone 4 is North Bend south to Shelter Cove, California; Zone 5 is south to San Francisco Bay.

³ In actuality, there were only 403 species, as the name of one species was inadvertently included twice (Holmes 2005). For the sake of consistency with the 1994 ROD, however, we will use the 404 figure here.

⁴ The 4 arthropod species groups are canopy herbivores (south range of Plan area), coarse wood chewers (south range), litter and soil dwelling species (south range), and understory forest gap herbivores (USDA and USDI 1994b: C-1).

⁵ As of this writing, disposition of a recent court ruling from a lawsuit over this program is still pending.

⁶ The riparian reserves have not been fully mapped, so there is no individual estimate of their areal extent nor the percent LSOG forest therein. However, USDA and USDI (2004b: 11) noted that “matrix and adaptive management area” land allocations constitute 19 percent of the Plan area. Presuming that “matrix” lands here do not constitute riparian reserves, one could estimate that riparian reserves might constitute $33-19=14$ percent of the Plan area. Added to the other

reserve lands, this totals $67+14=81$ percent of the Plan land area in reserves including riparian reserves. There is no mapped information, however, on the extent of LSOG forest in riparian reserves.

⁷ Intergovernmental Advisory Committee, adaptive management area subcommittee report – March 10, 2004 (<http://www.reo.gov/library/iac/letters/1910iac3.htm>).

⁸ Personal communication, Jose Linares, Forest Supervisor, Siuslaw National Forest, 4077 Research Way, Corvallis, OR 97333.